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Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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ABSTRACT

Objective To characterize the contributing factors that affect medical students' subspecialty choice and to estimate the extent of influence of individual factors on the students' decision-making process.

Design Systematic review and meta-analysis.

Methods A systematic search of the Cochrane Library, ERIC, Web of Science, CNKI and PubMed databases was conducted for studies published between January 1977 and October 2016. Information concerning study characteristics, influential factors, and the extent of their influence (EOI) was extracted independently by two trained investigators. EOI is the percentage level that describes how much each of the factors influenced students' choice of subspecialty. The estimates were pooled using a random-effects meta-analysis model due to the between-study heterogeneity.

Results Data were extracted from 72 studies (881,502 individuals). Overall, the factors influencing medical students' choice of subspecialty training mainly included academic interests (74.87%), competencies (55.15%), controllable lifestyles or flexible work schedules (53.06%), patient service orientation (49.35%), medical teachers or mentors (46.93%), career opportunities (44.00%), workload or working hours (37.92%), income (35.25%), length of training (32.30%), prestige (31.29%), advice from others (28.24%), and student debt (15.33%), with significant between-study heterogeneity

(P<0.0001). Subgroup analyses revealed that the EOI of academic interests was higher in developed countries than that in developing countries (79.30% [95% confidence interval (CI), 70.09%; 86.24%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.37 P=0.02). The EOI value of prestige was lower in developed countries than that in developing countries (24.45% [95% CI, 19.46%; 30.25%] vs. 48.02% [95% CI, 32.40%; 64.03%]; Q=4.31 P=0.01).

Conclusions This systematic review and meta-analysis provided a quantitative evaluation of the top 12 influencing factors associated with medical students' choice of subspecialty. Our findings provide the basis for the development of specific, effective strategies to optimize the distribution of physicians among different departments by modifying these influencing factors.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

- Our research emphasize that a reliable estimate of the factors associated with medical students' subspecialty choice is critical to obtaining a better understanding of students' perceptions, and the findings of the present study can facilitate the development of intervention strategies tailored to the needs of various healthcare systems.
- A large number of studies conducted in varied populations have been included.

- The differences in the characteristics of country, survey years, specialty, the type of data used and sample size across studies represent a major limitation of our study.

KEYWORDS Medical students, career choice, meta-analysis

Introduction

Medical students' choice of subspecialty represents the process that students' majored in medicine decide to choice a medical specialty, such as pediatrics and surgery, and their sub-discipline, such as nephrology and neurosurgery. With the development of the social economy and the improvement in people's living standards, the demand for physicians continues to increase; however, an imbalance in the supply of physicians in different subspecialties has become a growing concern in both developed and developing countries.[1 2] Some subspecialties, such as family medicine and palliative medicine,[3 4] are experiencing a desperate shortage of physicians, whereas other subspecialties, such as cardiology, ophthalmology and ear, nose and throat (ENT) surgery, require several years of training before admission due to intense competition.[5 6]

Specialty choice is the product of a complex interconnection of student expectation, department expectation, and competition for available spots, and student choice is where the choice begins.[7] Previous studies have suggested that medical students' choice of subspecialty is essential to the maintenance of an adequate medical workforce and a balanced development of the medical system.[8 9] However, the influencing factors underlying students' subspecialty choice have not been systemically reviewed. Recent changes in the training and practice environment may influence medical students' career choice.[10] Additionally, the variability in preferences over time and in students' attitudes towards career choices can further complicate this assessment. For example, a study in the UK indicated that half of the

medical students made a definitive subspecialty choice during their first year of medical school.[11] However, students were prone to changing their subspecialty preference during medical school and internship.[12] Notably, students may also reject certain subspecialties during their medical school training, even those they have previously seriously considered.[13] Therefore, identifying the factors that influence students' choice of subspecialty will enable a better understanding of the current shortage/overload of physicians in specific fields and contribute to policy-building and decision-making to improve the training and recruitment of students in the future.

We thus conducted a systematic review and a meta-analysis to investigate the influencing factors and the extent of their influence on the choice of subspecialty training among medical students. More specifically, we focused on the following questions. First, can we gain a better understanding of students' preferences for medical specialty according to the primary influencing factor? Second, do the subgroups according to world region and survey years examined in this study differ significantly with regard to the weight that students place on the identified influencing factor?

Methods

Search Strategy and Study Eligibility

Cross-sectional studies published between January 1977 and October 2016 that reported on factors influencing medical students' choice of subspecialty were identified using the Cochrane Library, Medline, Web of Science, CNKI and ERIC

databases. Articles were screened by title, abstract and reference list, and by correspondence with study investigators using the approach recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines **(Fig. S1).**[14] Potentially relevant papers were first identified by reviewing the titles and abstracts, and the full text of each retrieved article was then assessed. The search strategy is shown in **Methods S1**. Studies were included if they reported data on medical students, were published in peer-reviewed journals, and used a validated method to assess the extent of a factor's influence on the choice of subspecialty.

Data Extraction and Quality Assessment

The following information was independently extracted from each article by 2 trained investigators (Y.Y. and J.L.) using a standardized form: study design, geographic location, years of survey, journal, sample size, average age of the participants, the number and percentage of male participants, and the influencing factors and the extent of their influence. Each study may involve one or several influencing factors. The Newcastle-Ottawa Scale (NOS) recommended by the Agency for Healthcare Research and Quality (AHRQ), available at http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp, were used to assess the quality of the studies. All discrepancies were resolved via discussion and consensus.

Statistical Analysis

As considerable heterogeneity was expected because of the multiple sources of variances, a random effects meta-analysis model was used to estimate the influencing factors and the extent of their influence.[15] Between-study heterogeneity was assessed using the I^2 statistic, which was calculated to describe the percentage of total variation caused by heterogeneity across studies, with ≥50% indicating considerable heterogeneity. [16] [17] Potential sources of heterogeneity were identified using meta-regression.[18] Subgroup analyses were performed for each factor in the studies in developed countries vs. developing countries and studies conducted before 2010 vs. after 2010. The EOI value of competencies in developing countries was not statistically significant (81.21% [95% CI, 75.27%; 86.51%], P=0.1436), and no studies on the influence of student debt in developing countries were found. The Q-test based on the analysis of variance was used to compare the subgroups, with a significance threshold of 5%.[19] The influence of individual studies on the overall EOI value was explored by serially excluding each study in a sensitivity analysis. Publication bias was investigated using a funnel plot test and Egger's test.[20] [21] All analyses were performed using R (version 3.3.1, The R Foundation, Vienna, Austria). The statistical tests were 2-sided with a significance threshold of P<0.05.

Results

Study Characteristics

Seventy-two studies involving a total of 881,502 individuals were included in the present research **(Table 1).** Thirty-three studies were conducted in North America, 23 in Europe, 6 in Asia, 5 in Oceania, 3 in Africa, and 2 in South America. The median

number of participants per study was 254.5 (range 37-29,227). Thirteen studies included students who had already selected subspecialties, whereas 59 did not. The influencing factors for subspecialty choice were classified according to 17 aspects, including academic interests, controllable lifestyle or flexible work schedule (defined as flexibility that allows physicians to control the number of hours devoted to practicing the specialty), competencies, patient service orientation, medical teachers or mentors, career opportunities, workload or working hours (characterized by the physician's time spent on professional responsibilities), income, prestige, length of training, advice from others (advice from family, friends, and other students), student debt, experience with the subject, working environment, personality, gender and job security. The influencing factors were ranked according to the frequency of occurrence and each factor was identified when at least 5 papers were available describing it. Personality and gender are common factors that affect the choice of subspecialty among medical students, but most of the relevant literature has not reported on the extent of these factors' influence. Moreover, the funnel plots were clearly asymmetrical with regard to experience with the subject, the working environment and job variety, indicating the existence of publication bias. Thus, the analysis of the remaining 12 influencing factors were shown in this paper. Quality assessment scores for the included studies are listed in **Table 1**. None of the studies received a point for the second AHRQ Quality Indicator, which requires studies to list the inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications, since no comparison studies were referenced in the analyzed articles. For the remaining 10 criteria, 6 studies received 9

points, 8 studies received 8 points, 17 studies received 7 points, 32 studies received 6 points, 7 studies received 5 points and 2 studies received 4 points (scores for individual studies are presented in **Table S1**).

Primary Analysis

A meta-analysis was performed on the 12 influencing factors **(Table 2)**: academic interests **(Fig. S2)**, competencies **(Fig. S3)**, controllable lifestyle or flexible work schedule **(Fig. S4)**, patient service orientation **(Fig. S5)**, medical teachers or mentors **(Fig. S6)**, career opportunities **(Fig. S7)**, workload or working hours **(Fig. S8)**, income **(Fig. S9)**, length of training **(Fig. S10)**, prestige **(Fig. S11)**, advice from others **(Fig. S12)** and student debt **(Fig. S13)**. All the factors were significant with evidence of between-study heterogeneity ($P<0.0001$). A sensitivity analysis, in which the meta-analysis was serially repeated after the exclusion of each study, demonstrated that no individual study affected the overall extent of a factor's influence.

Meta-regression and Subgroup Analysis

Using common instructions when at least 5 studies were available and at least 2 studies were in each comparator subgroup, four categorical covariates were identified as potential sources of heterogeneity by examining the studies conducted in the United States (US) vs. the studies conducted in other countries, the studies conducted before 2010 vs. those conducted after 2010, the studies concerning subspecialty only vs. those that were not specific to a subspecialty, and the studies with a sample size

<200 vs. the studies with a sample size ≥200 **(Table 3).** Some of the heterogeneities observed among the 12 factors can be partially explained by country, survey years, specialty and sample size.

EOI values were further analyzed by subgroup **(Table S2)** according to world region **(Fig. 1)** and survey year **(Fig. 2).** The EOI value of academic interests in developed countries was higher than that in developing countries (79.30% [95% CI, 70.09%; 86.24%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.37 P=0.02). Conversely, a lower EOI value of prestige was found in studies conducted in developed countries than in developing countries (24.45% [95% CI, 19.46%; 30.25%] vs. 48.02% [95% CI, 32.40%; 64.03%]; Q=4.31 P=0.01). No statistically significant subgroup differences in the EOI values of the other influencing factors were noted between developed countries and developing countries**.** In addition, no statistically significant differences in the EOI values of the influencing factors were observed when subgroup analysis was performed by survey year.

Assessment of Publication Bias

We generated a funnel plot with proportion as the abscissa and standard error as the ordinate. A visual inspection of the funnel plots revealed minimal asymmetry among the various influencing factors **(Fig. S14)**, and the results were concentrated in the narrow upper part of the graph. However, there was evidence of small study effect in the meta-analysis of "patient service orientation" (Egger's test P=0.02).

Discussion

Implications

This systematic review and meta-analysis involved 72 studies with 881,502 medical students. Twelve influencing factors were analyzed. These factors can be classified into two categories: economic factors and non-economic factors. We found that the EOI of the economic factors, including income (35.25%) and student debt (15.33%), may not depend on the region's level of economic development. However, income remained a major influencing factor in the process of choosing a subspecialty. In the US, 15% of full-time family medicine physicians earned less than $100,000 in 2004, which is significantly less than the income earned by invasive cardiologists (median income=$427,815), neurosurgeons (median income=$211,094), and orthopedists (median income=$335,646).[22] This economic inequality made family medicine less attractive to medical school graduates.[23] Benefits such as health insurance and tuition reimbursement have been shown to be the most common economic incentives used to attract applicants.[24]

The non-economic factors can be divided into individual factors, specialty-related factors and others. First, individual factors, including academic interest and competencies, have a considerable impact on students' subspecialty choice, with EOI values of 74.87% and 55.15%, respectively. In addition, in the subgroup analysis, although academic interests were less influential in developing countries than in developed countries (79.30% [95% CI, 70.09%; 86.24%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.37 P=0.02), they were still the most influential of the 12 factors regardless of regional economic level. These findings indicate that

subspecialties with a shortage of manpower may attract more students by increasing students' interests and improving the quality of education. Previous studies indicated that early subspecialty exposure in medical education may arouse students' academic interest and improve their clinical competence.[23 25] For example, an elective extracurricular program designed to facilitate early contact with family medicine physicians was found to significantly improve students' interest and clinical skills, especially communication skills, in family medicine.[26] Furthermore, dispelling myths and espousing the positive aspects of a discipline may provide a better understanding of certain subspecialties; this approach could also be effective in increasing students' academic interest.[27] For instance, family medicine is often considered a discipline that requires less professional skills and knowledge. This misconception demotivates students from choosing family medicine as their future career subspecialty, and this trend may eventually lead to a shortage of family physicians.[27] Eliminating such prejudices may help students pay greater attention to the areas in short supply and restore their interests in other specialties.

Second, the specialty-related factors included controllable lifestyle/flexible work schedule (EOI of 53.06%), career opportunities (EOI of 44.00%), workload (EOI of 37.92%) and training length (EOI of 32.30%). Of these factors, lifestyle varied between different areas. Additionally, although certain specialties, such as general surgery, seem to have an adequate number of surgeons on a per capita basis in the US, there is still a poor geographic distribution within the surgical workforce according to the type of surgical practice.[28] The inflexible lifestyle is a common reason that

students perceive surgery to be less attractive.[28] Reorganization of expected work hours within shared practices and the increased use of physician extenders and technologies such as electronic medical records may give physicians more flexibility in work schedules.[29] Moreover, providing promotion opportunities and shortening the length of training are possible strategies to recruit new staff in subspecialties that require a long period of post-graduate residency training, such as neurosurgery.[30]

Finally, other factors such as service orientation (EOI of 49.35%), medical teachers or mentors (EOI of 46.93%), prestige (EOI of 31.29%), and advice from others (EOI of 28.24%) also contribute to the decision-making process of medical students. For example, the desire to care for patients with end-stage diseases contributed to the decision to enter palliative medicine in 86% of the medical students.[4] Additionally, exposure to mentors in a particular clinical field such as internal medicine has been strongly associated with medical students' choice of clinical field.[31] Moreover, improving the occupational prestige of areas such as family medicine, pathology, and radiology may help reshape the distribution of the workforce. [25 32 33]

In our study, several findings are especially noteworthy. First, interest was far more important than income in deciding subspecialty. In our study, interest was the top-ranked influencing factor (EOI of 74.87%) of subspecialty choice, while income was ranked lower (EOI of 35.25%). This finding argues against the possible default belief that raising physician's wages alone could solve the uneven distribution of clinicians among subspecialties. Our findings highlight that cultivating and stimulating students' professional interests may help improve the maldistribution of

medical resources in a more efficient and cost-saving manner.

Second, improving abilities in a certain subspecialty of interest can greatly affect medical students' professional choice. In our study, competencies ranked second in influence, which may reflect the impact of admission conditions on students' choice of subspecialty. Hence, to reduce the risk that students are restricted to the subspecialty of their interest due to a lack of personal skills, medical education should focus more on enhancing students' personal competencies in addition to their academic interests.

Third, balancing medical resources is a complex process in practical terms, as the influencing factors are not mutually exclusive. The shortage of physicians in certain subspecialties may increase physician workload, resulting in less time for teaching. Hence, the quality of teaching cannot be guaranteed, and students may tend to avoid choosing these subspecialties, thus worsening the imbalance in the medical workforce. Additionally, some of the 12 factors identified are not amenable to practical interventions. For example, prestige cannot be immediately increased using interventional strategies.[32] Overall, effective strategies must be multi-pronged and incorporate several different aspects, and maldistribution in the workforce should not be tackled through a simple adjustment of one influencing factor.

Interpretations of the results of this meta-analysis

Our meta-regression stratified by the study-level characteristics found that country, survey years, subspecialty and sample size may contribute to the heterogeneity

between studies. There was no significant difference in the sensitivity analysis, which indicated that the results of the meta-analysis were convincing. The funnel plots and Egger's tests revealed that most of the publication bias was small (P>0.05), except for the meta-analysis of "patient service orientation". Moreover, the majority of the studies collected in the database were from developed countries rather than developing countries.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the students involved in our study included medical students at different stages of their medical education. Students' perception about different subspecialties may change during medical training. For example, compared to an intern, a freshman student may place greater emphasis on income and prestige when considering a career choice.[34] Second, our meta-analysis summarized the data from different geographic regions around the world, and the general conclusions may not be appropriate to guide policy development in each region. Enhanced effort is needed to develop specific intervention strategies according to the specific medical career grade, economic level, religious beliefs, healthcare system, educational system and endemic diseases of different countries and regions. Third, the surveys in the various studies were also conducted using different methods. Most of the questionnaires used a Likert scale. Therefore, when we converted the results to a percentage representing the extent of a factor's influence, the Likert scale items were treated as interval data.[35-37] Consequently, there may have been differences in the conversion process.

Fourth, a secondary meta-analysis of longitudinal studies may better reflect changes in influencing factors and the extent of their influence over time. Finally, the analysis relied on aggregated published data. A multicenter prospective study would provide a more accurate estimate of the influencing factors and the extent of their influence on medical students' choice of subspecialty.

Conclusion

In conclusion, this systematic review and meta-analysis provided a summary evaluation of 12 influencing factors and the extent of their influence on the choice of subspecialty training among medical students. Understanding students' attitudes toward their subspecialty decision-making process could provide the basis for developing strategies to increase the attractiveness of subspecialties experiencing a shortage of manpower, thereby balancing the distribution of medical recourses.

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Legends

Table 1. Selected Characteristics of the 76 Studies Included in this Systematic Review and Meta-analysis

Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Figure 1. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region.

Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

Supplements

Methods S1. Search strategy used in the current systematic review and meta-analysis.

Table S1. Quality Assessment of the Included Studies.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Figure S1. Flow Diagram of the Study Inclusion Process.

Figure S2. Forest Plot of "Academic Interest".

Figure S3. Forest Plot of "Competencies".

Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

Figure S5. Forest Plot of "Patient Service Orientation".

Figure S6. Forest Plot of "Medical Teachers or Mentors".

Figure S7. Forest Plot of "Career Opportunities".

Figure S8. Forest Plot of "Workload or Working Hours".

Figure S9. Forest Plot of "Income".

Figure S10. Forest Plot of "Length of Training".

Figure S11. Forest Plot of "Prestige".

Figure S12. Forest Plot of "Advice from Others".

Figure S13. Forest Plot of "Student Debt".

Figure S14. Funnel Plots of the Publication Bias Tests of the 12 Factors.

Table 1. Selected Characteristics of the 76 Studies Included in this Systematic Review and Meta-analysis

First Author, Year	Country	Survey years	Sample size	Average age	Men, No. (%)	Scores
Smith et al,[38] 2015	UK	2012	2,978	NR	NR	6
Cochran et al,[39] 2005	USA	2002	408	27.2	214 (52.45)	5
Hauer et al,[40] 2008	USA	2007	1,177	NR	NR	6
Johnson et al,[41] 2012	USA	2012	622	NR	NR	6
Kiolbassa et al,[42] 2011	Germany	2010	1,114	24.1	408 (36.62)	5
Klingensmith et al,[43] 2015	USA	2013	792	NR	539 (68.06)	6
Lee et al,[44] 2012	USA	2012	100	NR	58 (58)	7
Macdonald et al,[45] 2012	New Zealand	2011	134	NR	79 (58.96)	7
Parsa et al,[34] 2010	Iran	2006-2007	137	27.34	49 (35.77)	7
Paiva et al,[46] 1982	USA	1982	144	NR	NR	6
Ni Chroinin et al,[47] 2013	UK	2009-2011	274	NR	112 (40.89)	7
Newton et al,[29] 2005	USA	1998-2004	1,258	NR	642 (51.03)	8
Rogers et al,[48] 1990	USA	1989	266	NR	205 (77.07)	6
Abendroth J et al,[49] 2014	Germany	2007-2012	45	NR	14 (31)	7
Alawad et al,[50] 2015	USA	2010-2011	45	NR	36 (80)	8
Azizzadeh et al,[51] 2003	USA	2002	130	NR	NR	6
Celenza et al,[52] 2012	Australia	2009	216	NR	121 (56.02)	8
Dolan-Evans et al,[53] 2014	Australia	2013	419	NR	215 (51.31)	8
Boyd et al,[54] 2009	USA	2005-2006	5,848	NR	2,982 (50.99)	8
Egerton et al,[55] 1985	Ireland	1977-1981	134	30	82 (61.19)	6
Diderichsen et al,[56] 2013	Sweden	2006-2009	372	27	157 (42.20)	6
Ferrari et al,[57] 2013	Italy, UK	2009-2011	45	25	NR	9
Freire et al,[58] 2011	Brazil	2006-2008	290	23	102 (35.17)	7
Buddeberg-Fischer et al,[59] 2006	Switzerland	2001-2003	522	31.1	241 (46.17)	9
Dorsey et al,[60] 2005	USA	2003	11,029	NR	4,964 (45.01)	6
Ekenze et al,[61] 2013	Nigeria	2009-2010	96	25.9	NR	7
Barikani et al,[62] 2012	Australia	2008-2009	49	21.7	NR	6
Bittaye et al,[63] 2012	Gambia	2011	106	24.1	48 (45.28)	6
Bonura et al,[64] 2016	USA	2015	590	NR	321 (54.40)	9
Al-Fouzan et al,[65] 2012	Kuwait	2011-2012	144	NR	NR	7
AlKot et al,[66] 2015	Egypt	2013	451	21.8	NR	7
Borges et al,[67] 2009	USA	2001-2005	341	NR	NR	5
Budd et al,[68] 2011	UK	2011	870	22	NR	7
Corrigan et al,[69] 2007	Ireland	2007	222	NR	142 (63.96)	7
Davis et al,[70] 2016	UK	2016	173	NR	76 (43.93)	7

Deutsch et al,[71] 2015	Germany	2011	659	27.9	NR	8
Gardner et al,[72] 2014	Australia	1993-2005	631	NR	NR	7
Dias et al,[73] 2013	UK	2013	495	NR	438 (88.48)	5
Goltz et al,[74] 2013	USA	2012	102	24.5	34 (33.33）	6
Gupta et al,[75] 2013	India	2013	243	NR	179 (73.36)	6
Hanzlick et al,[76] 2008	USA	2006	161	NR	NR	6
Harris et al,[77] 2005	USA	1991-2002	104	NR	53 (50.96)	6
Hauer et al,[78] 2008	USA	2008	80	NR	NR	6
Labiris et al,[79] 2014	Greece	2014	111	23.6	55 (49.54)	6
Lambert et al,[80] 2008	UK	2007	17,393	NR	NR	6
Shah et al,[81] 2012	USA	2011	892	NR	NR	6
Lefevre et al,[82] 2010	USA	2008	1,555	NR	589 (37.88)	6
Vicente et al,[83] 2013	Chile	2013	30	NR	NR	6
Wiesenfeld et al,[84] 2014	Canada	2013	60	NR	NR	7
Lam et al,[85] 2016	Hong Kong	2015	228	23	NR	9
Hartung et al,[86] 2005	USA	2004	192	20.59	74 (38.54)	4
Girasek et al,[87] 2011	Hungary	2011	536	NR	NR	5
Zuccato et al,[88] 2015	Canada	2012	37	NR	24 (65)	6
Wilbanks et al,[89] 2015	USA	2011-2013	29,227	NR	15,164 (51.99)	9
West et al,[90] 2009	USA	2005-2007	14,890	NR	8,700 (58.43)	6
Watmough et al,[91] 2007	UK	2005	116	NR	66 (56.90)	4
Thakur et al,[92] 2001	USA	2001	56	NR	53 (95)	8
Scott et al,[93] 2011	Canada	2002-2004	1,542	NR	NR	6
Schnuth et al,[94] 2003	USA	2002	203	NR	72 (53.47)	6
Richards et al,[95] 2009	UK	2009	150	NR	108 (72.00)	5
Reed et al,[96] 2009	USA	2008	2,022	NR	1,354 (66.96)	9
de Souza et al,[97] 2015	Portugal	2012	1,303	NR	NR	7
Pikoulis et al,[98] 2010	Greece	2006-2007	87	NR	NR	6
Ozer et al,[99] 2015	Turkey	2013	98	27.7	26 (26.53)	6
Noble et al,[100] 2004	Canada	2004	21,296	NR	NR	8
Noble et al,[101] 2010	Canada	2007	120	NR	NR	5
Newton et al,[102] 2005	USA	2004	1,286	NR	NR	6
Moore et al,[103] 2012	USA	2011	337	26	179 (53.12)	6
Momen et al,[104] 2015	Iran	2014-2015	38	35.6	11 (29)	6
Mehmood et al,[105] 2012	Saudi Arabia	2012	550	NR	348 (63.27)	6
Loriot et al,[106] 2010	France	2007	44	NR	17 (39)	7
Lefevre et al,[107] 2010	France	2008	522	23.8	198 (37.93)	7

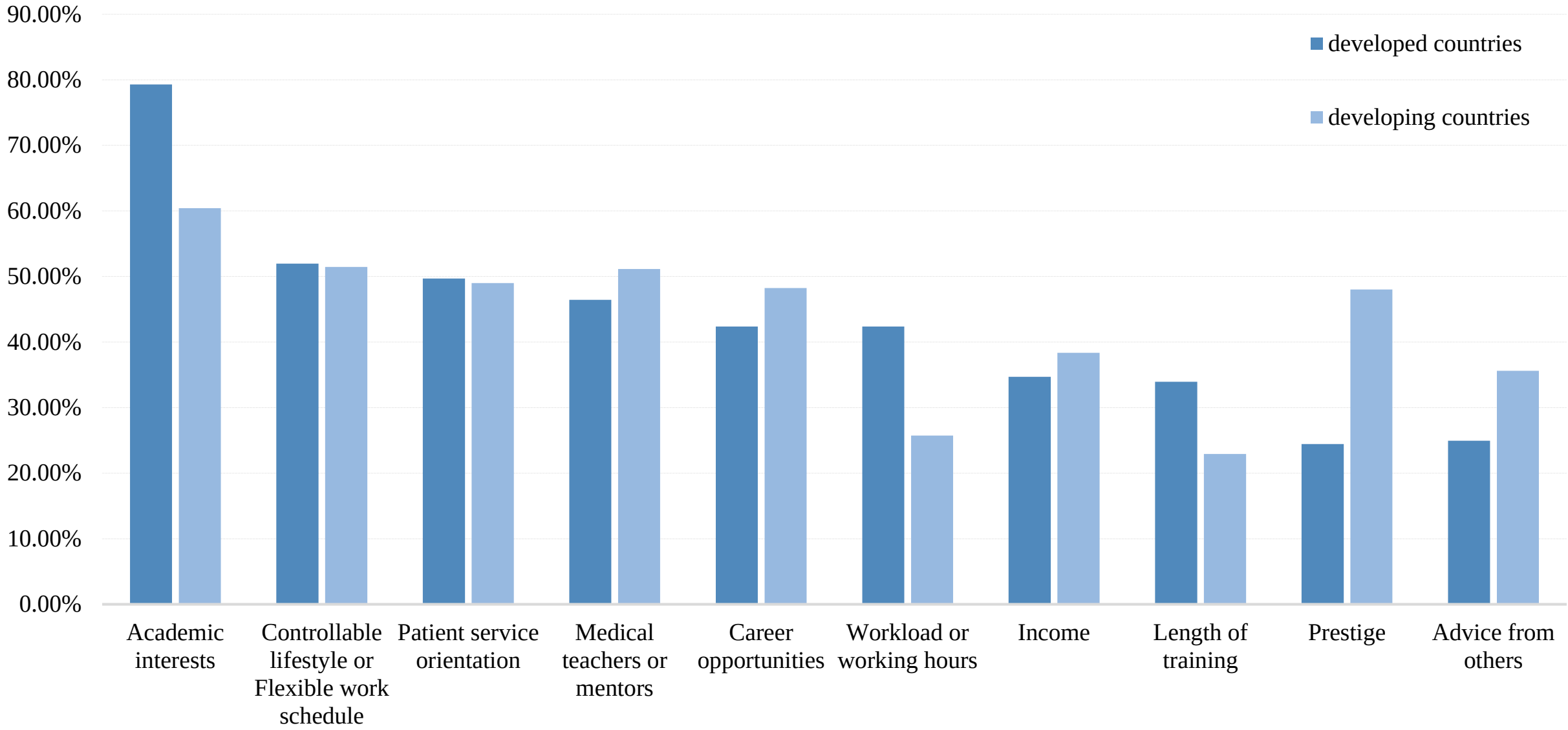
Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Factor	No. of studies	Total no. of participants	EOI value (%)	*I-square* (%)	*Tau-square*	*P*-Value
Academic interests	37	82,276	74.87	99.80	1.60	<0.0001
Competencies	17	76,515	55.15	99.90	3.44	<0.0001
Controllable lifestyle or flexible work schedule	42	102,384	53.06	99.50	0.45	<0.0001
Patient service orientation	34	45,865	49.35	98.70	0.41	<0.0001
Medical teachers or mentors	32	85,071	46.93	99.80	1.14	<0.0001
Career opportunities	38	81,923	44.00	99.70	1.15	<0.0001
Workload or working hours	19	21,870	37.92	98.40	0.72	<0.0001
Income	49	109,610	35.25	99.70	1.09	<0.0001
Length of training	18	42,046	32.30	98.10	0.20	<0.0001
Prestige	24	30,012	31.29	98.40	0.53	<0.0001
Advice from others	18	82,692	28.24	99.80	0.02	<0.0001
Student debt	8	38,917	15.33	98.80	0.27	<0.0001

Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Factor		*P*-Value
Academic interests	Country	0.6302
	Survey years	0.2711
	Specialty	0.4008
	Sample size	0.6537
Competencies	Country	0.8376
	Survey years	0.0151
	Specialty	0.9398
	Sample size	0.5823
Controllable lifestyle or flexible work schedule	Country	0.9614
	Survey years	0.9822
	Specialty	0.0035
	Sample size	0.7203
Patient service orientation	Country	0.0833
	Survey years	0.8524
	Specialty	0.0010
	Sample size	0.6358
Medical teachers or mentors	Country	0.0007
	Survey years	0.6376
	Specialty	0.8141
	Sample size	0.5894
Career opportunities	Country	0.5828
	Survey years	0.7546
	Specialty	0.0077
	Sample size	0.0081
Workload or working hours	Country	0.3981
	Survey years	0.3922
	Specialty	0.1070
	Sample size	0.8205
Income	Country	0.7390
	Survey years	0.8774
	Specialty	0.0480
	Sample size	0.6786
Length of training	Country	0.7854
	Survey years	0.7229
	Specialty	0.5667
	Sample size	0.7082
Prestige	Country	0.3485

	Survey years	0.0950
	Specialty	0.0172
	Sample size	0.5214
	Country	0.9328
Advice from others	Survey years	0.0057
	Specialty	<0.0001
	Sample size<200	<0.0001
	Country	0.0001
Student debt	Survey years	0.5502
	Sample size	0.0343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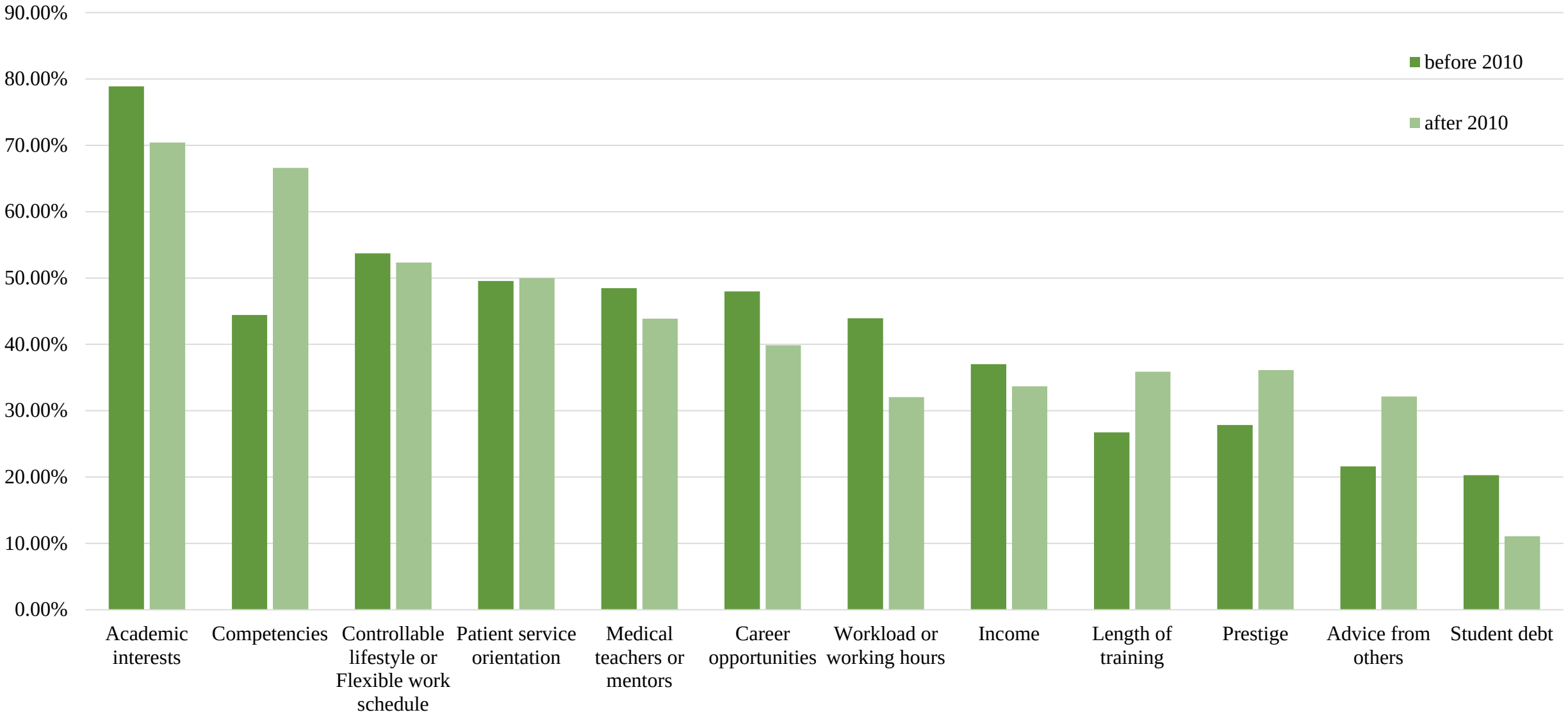
Workload or working hours
Income
Length of training
Prestige
Advice from others


90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
before 2010
after 2010
Academic interests
Competencies
Controllable lifestyle or Flexible work schedule
Patient service orientation
Medical teachers or mentors
Career opportunities
Workload or working hours
Income
Length of training
Prestige
Advice from others
Student debt

SI Methods. Search strategy used in the current systematic review and meta-analysis.

Medical Students

1. Students, Medical [Mesh]
2. Medical students
3. Medical student
4. Student, Medical
5. OR / 1 – 4

Subspecialty Choice

6. Career choices
7. Choice, Career
8. Choices career
9. Specialties
10. Sub-specialties
11. Sub-descipline
12. OR / 6 – 11

Study design

13. Cross sectional study
14. Cross sectional study [Publication Type]
15. Cross sectional study [Mesh Terms]
16. Systematic review
17. Systematic review [Publication Type]
18. Systematic review [Mesh Terms]
19. Meta-analysis [Title/Abstract]
20. Meta-analysis [Mesh Terms]
21. Meta-analysis [Publication Type]
22. OR / 12 – 21

Factors

23. Factors

Combined search

24. #5 AND #12AND #22 AND #23

Abbreviations: MeSH, Medical Subject Heading in Pubmed.

Table S1. Quality assessment of the included studies

Quality assessment criteria		1	2	3	4	5	6	7	8	9	10	11	Scores
1	Smith et al,[38] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
2	Cochran et al,[39] 2005	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
3	Hauer et al,[40] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
4	Johnson et al,[41] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
5	Kiolbassa et al,[42] 2011	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
6	Klingensmith et al,[43] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
7	Lee et al,[44] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
8	Macdonald et al,[45] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
9	Parsa et al,[34] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
10	Paiva et al,[46] 1982	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
11	Ni Chroinin et al,[47] 2013	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
12	Newton et al,[29] 2005	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
13	Rogers et al,[48] 1990	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
14	Abendroth J et al,[49] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	Y	7
15	Alawad et al,[50] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	N	8
16	Azizzadeh et al,[51] 2003	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
17	Celenza et al,[52] 2012	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
18	Dolan-Evans et al,[53] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	Y	8
19	Boyd et al,[54] 2009	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
20	Egerton et al,[55] 1985	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
21	Diderichsen et al,[56] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
22	Ferrari et al,[57] 2013	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
23	Freire et al,[58] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
24	Buddeberg-Fischer et al,[59] 2006	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
25	Dorsey et al,[60] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
26	Ekenze et al,[61] 2013	Y	U	Y	Y	Y	Y	Y	N	N	Y	N	7
27	Barikani et al,[62] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
28	Bittaye et al,[63] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
39	Bonura et al,[64] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
30	Al-Fouzan et al,[65] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
31	AlKot et al,[66] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
32	Borges et al,[67] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
33	Budd et al,[68] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
34	Corrigan et al,[69] 2007	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
35	Davis et al,[70] 2016	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
36	Deutsch et al,[71] 2015	Y	U	Y	Y	Y	Y	N	Y	Y	Y	N	8
37	Gardner et al,[72] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	7
38	Dias et al,[73] 2013	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
39	Goltz et al,[74] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
40	Gupta et al,[75] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
41	Hanzlick et al,[76] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
42	Harris et al,[77] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
43	Hauer et al,[78] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
44	Labiris et al,[79] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
45	Lambert et al,[80] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
46	Shah et al,[81] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
47	Lefevre et al,[82] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
48	Vicente et al,[83] 2013	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
49	Wiesenfeld et al,[84] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
50	Lam et al,[85] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
51	Hartung et al,[86] 2005	Y	U	Y	Y	N	Y	N	N	N	N	N	4
52	Girasek et al,[87] 2011	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
53	Zuccato et al,[88] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
54	Wilbanks et al,[89] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
55	West et al,[90] 2009	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
56	Watmough et al,[91] 2007	Y	U	Y	Y	N	N	N	N	N	Y	N	4
57	Thakur et al,[92] 2001	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
58	Scott et al,[93] 2011	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
59	Schnuth et al,[94] 2003	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
60	Richards et al,[95] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
61	Reed et al,[96] 2009	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
62	de Souza et al,[97] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
63	Pikoulis et al,[98] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
64	Ozer et al,[99] 2015	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
65	Noble et al,[100] 2004	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
66	Noble et al,[101] 2010	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
67	Newton et al,[102] 2005	Y	U	Y	Y	N	Y	Y	N	N	Y	N	6
68	Moore et al,[103] 2012	Y	U	Y	Y	Y	Y	N	Y	N	N	N	6
69	Momen et al,[104] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
70	Mehmood et al,[105] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
71	Loriot et al,[106] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
72	Lefevre et al,[107] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7

Quality assessment criteria in detail

1. Define the source of information (survey, record review).

2. List the inclusion and exclusion criteria for the exposed and unexposed subjects (cases and controls) or refer to previous publications.

3. Indicate the time period used for identifying patients.

4. Indicate whether the subjects were consecutive if not population-based.

5. Indicate whether the evaluators of the subjective components of the study were masked to the other aspects of participants' status.

6. Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)

7. Explain any patient exclusion from the analyses.

8. Describe how confounding was assessed and/or controlled.

9. If applicable, explain how missing data were handled in the analysis.

10. Summarize the patient response rates and the completeness of the data collection.

11. Clarify what follow-up, if any, was expected and the percentage of patients with incomplete data or follow-up.

"Y": Yes; "N": No; "U": Unclear.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Factor		No. of studies	Total no. of participants	Extent of influence (%)	*P*-Value	*Q*-Value
Academic interest	developed	27	79,910	79.30	0.02	3.37
	developing	10	2,366	60.41		
	before 2010	29	44,174	78.88	0.33	1.40
	after 2010	8	38,102	70.44		
Competencies	before 2010	9	43,134	44.44	0.21	1.86
	after 2010	8	33,381	66.60		
Controllable lifestyle or flexible work schedule	developed	36	100,799	51.97	0.53	0.89
	developing	6	1,581	51.47		
	before 2010	22	62,945	53.72	0.99	0.02
	after 2010	20	39,439	52.34		
Patient service orientation	developed	25	43,964	49.69	0.99	0.02
	developing	9	1,901	48.99		
	before 2010	18	40,997	49.56	0.83	0.31
	after 2010	16	4,868	49.97		
Medical teachers or mentors	developed	28	84,076	46.43	0.73	0.48
	developing	4	995	51.14		
	before 2010	21	49,654	48.48	0.70	0.54
	after 2010	11	35,417	43.87		
Career opportunities	developed	31	79,867	42.36	0.60	0.74
	developing	7	2,056	48.24		
	before 2010	20	43,417	47.97	0.24	1.68
	after 2010	18	38,506	39.87		
Workload or working hours	developed	14	20,789	42.36	0.34	1.35
	developing	5	1,081	25.72		
	before 2010	9	19,456	43.93	0.42	1.17
	after 2010	10	2,414	32.04		
Income	developed	38	106,910	34.69	0.90	0.17
	developing	11	2,700	38.36		
	before 2010	25	68,714	37.01	0.50	0.95
	after 2010	24	40,896	33.69		
Length of training	developed	15	41,246	33.95	0.31	1.48
	developing	3	800	22.92		
	before 2010	7	8,811	26.72	0.28	1.59
	after 2010	11	33,234	35.87		
Prestige	developed	16	27,806	24.45	0.01	4.31
	developing	8	2,206	48.02		
	before 2010	12	25,542	27.86	0.25	1.67
	after 2010	12	4,470	36.12		
Advice from others	developed	14	81,205	24.95	0.36	1.33
	developing	4	1,487	35.62		
	before 2010	10	48,319	21.61	0.31	1.47
	after 2010	8	34,373	32.13		
Student debt	before 2010	5	6,610	20.29	0.69	0.59
	after 2010	3	32,307	11.08		

Figure S1. Flow Diagram of the Study Inclusion.

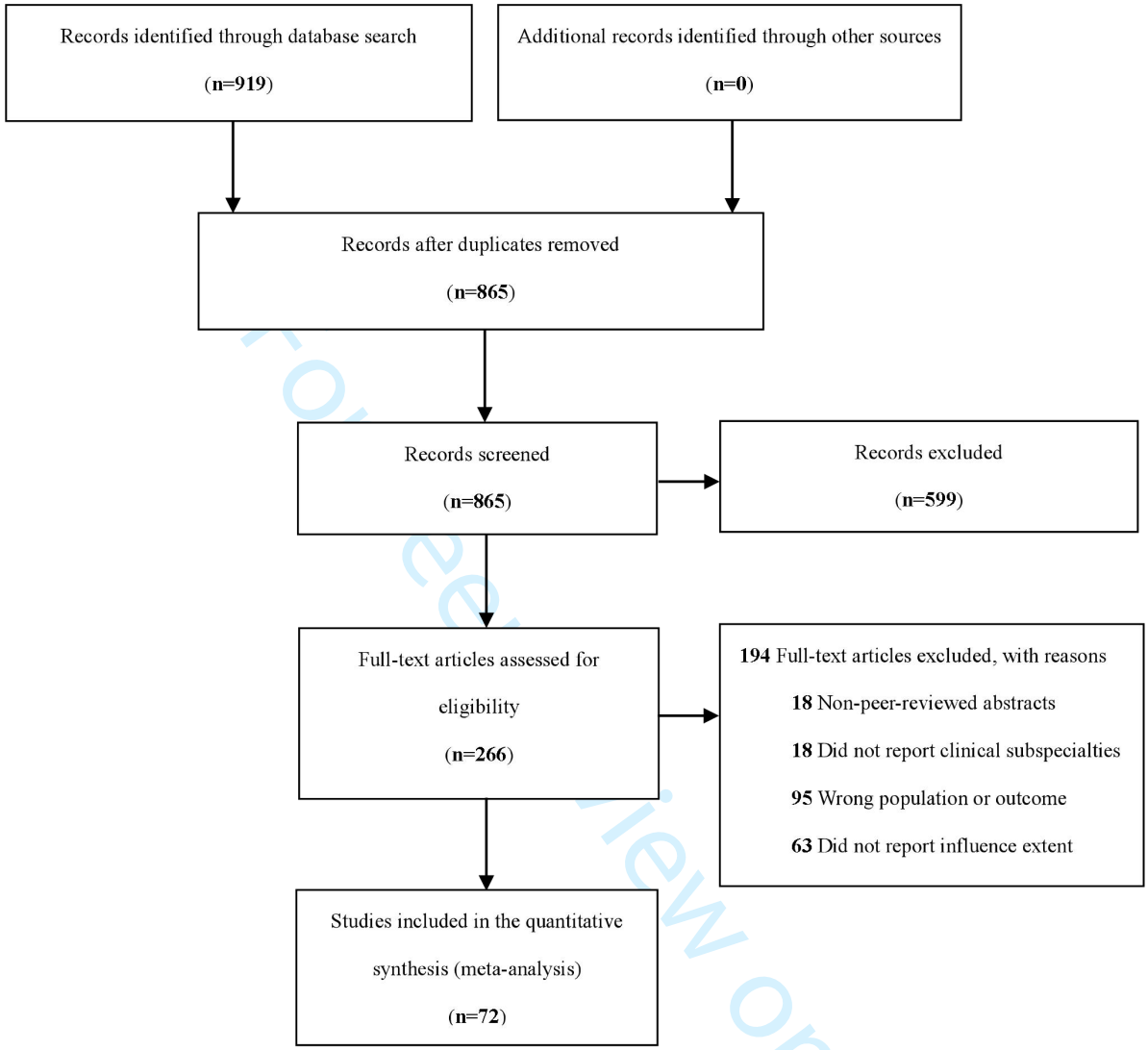


Figure S2. Forest Plot of "Academic Interest".

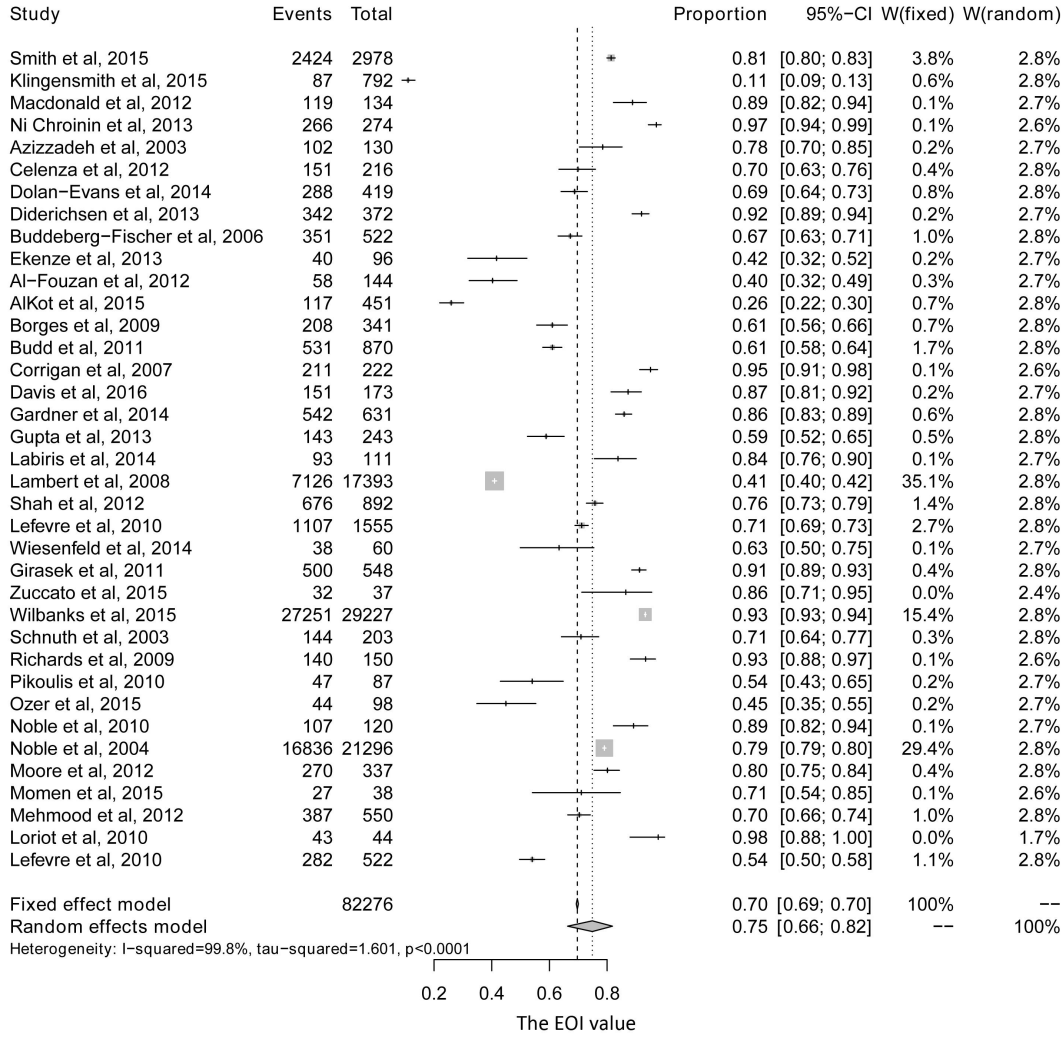


Figure S3. Forest Plot of "Competencies".

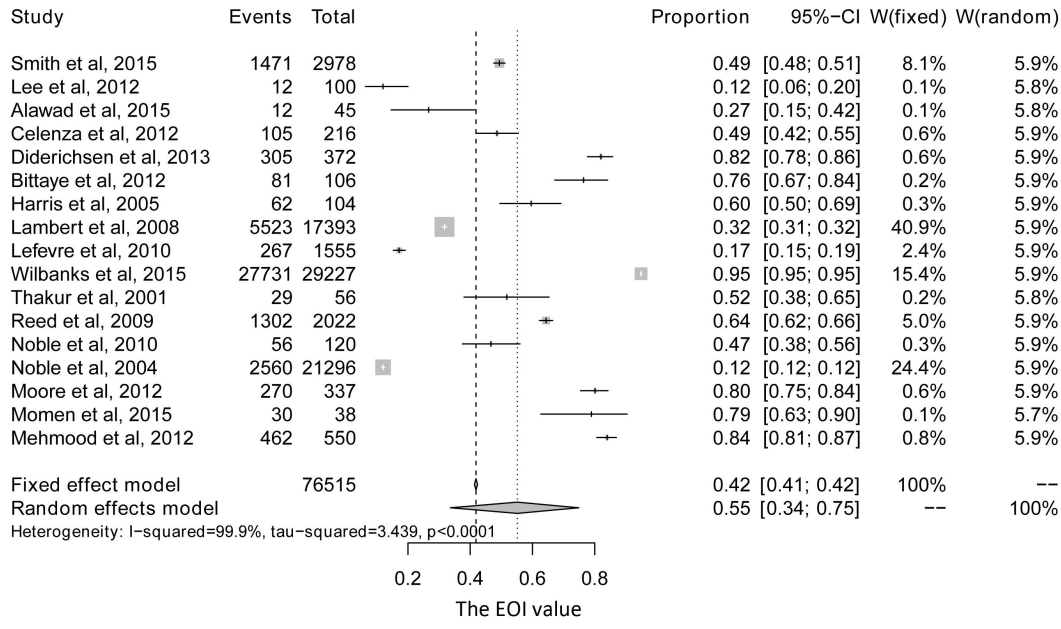


Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

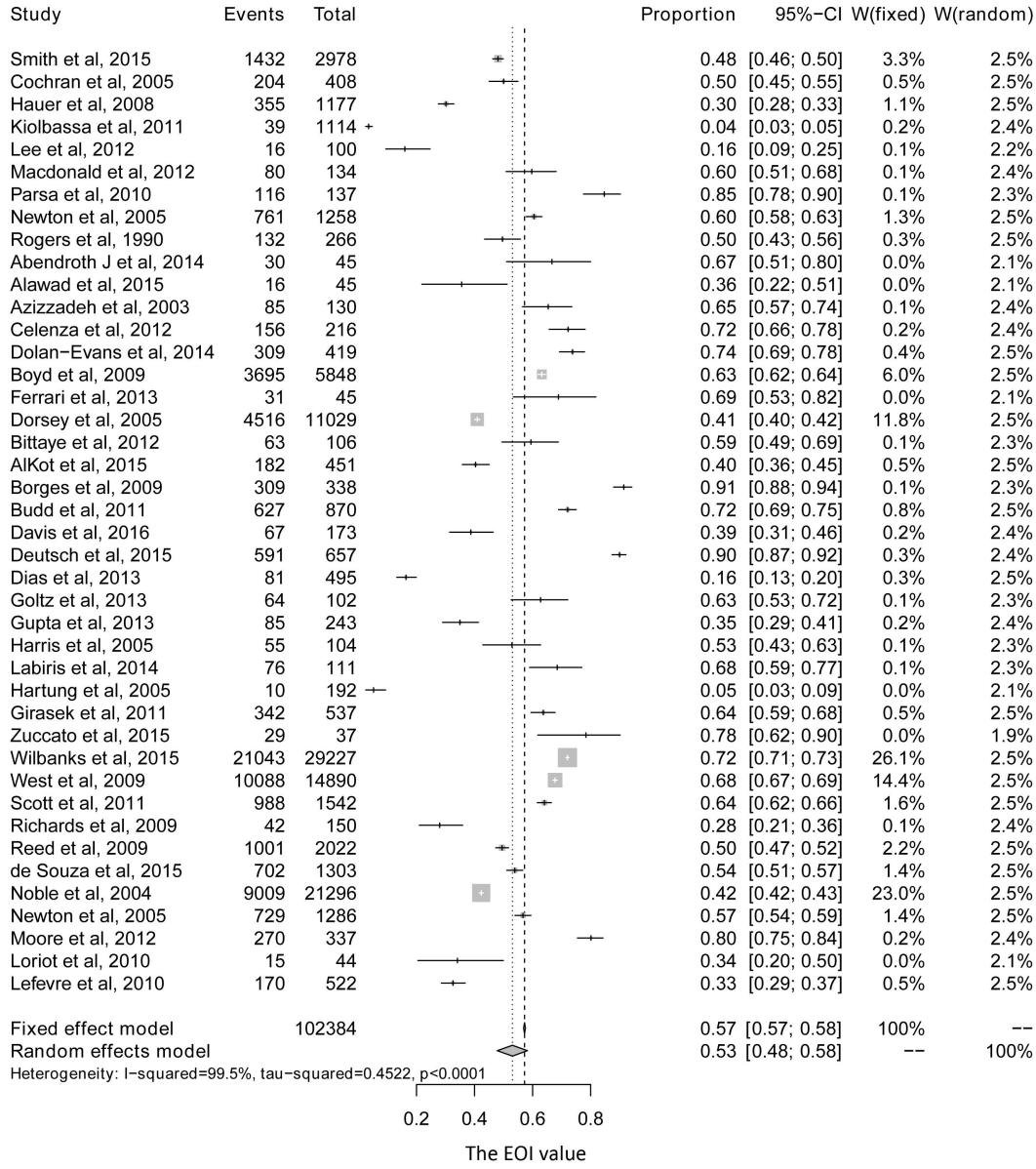


Figure S5. Forest Plot of "Patient Service Orientation".

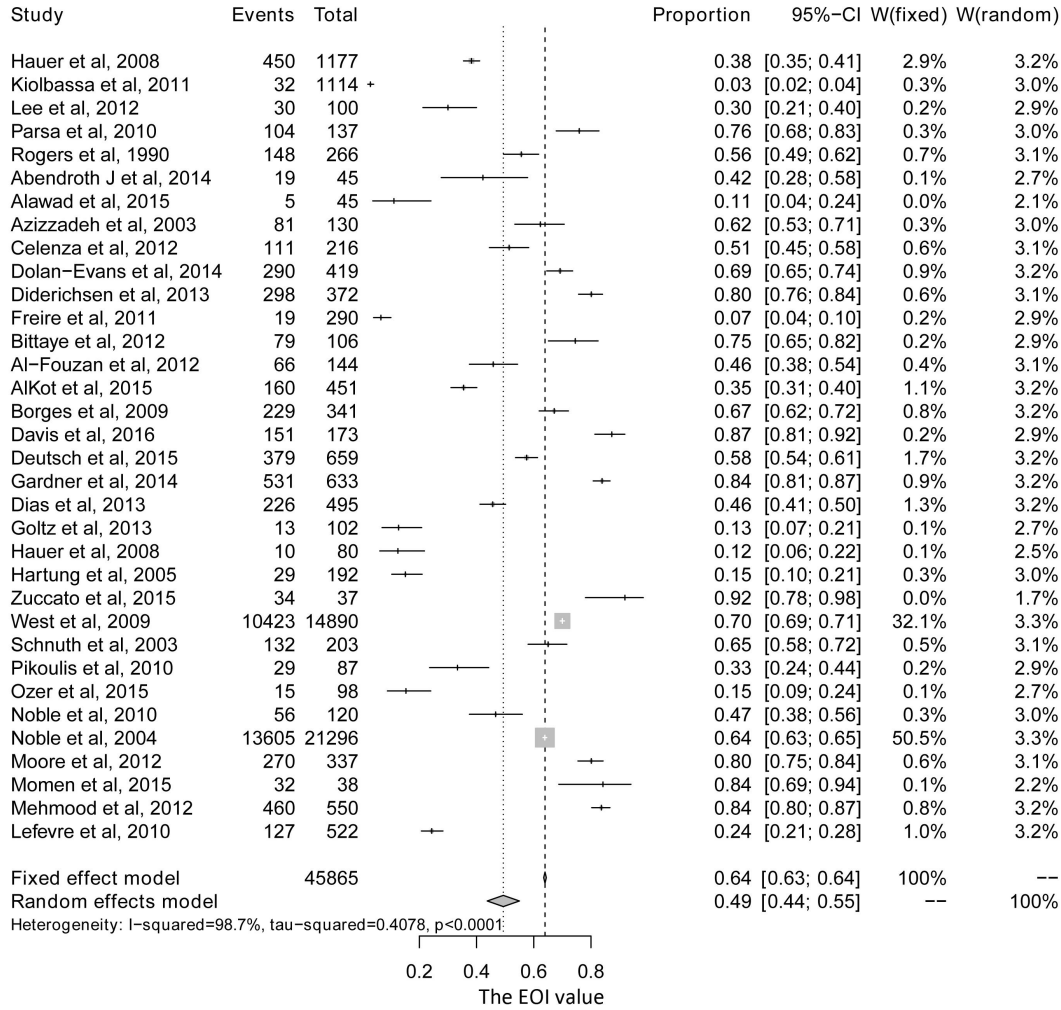


Figure S6. Forest Plot of "Medical Teachers or Mentors".

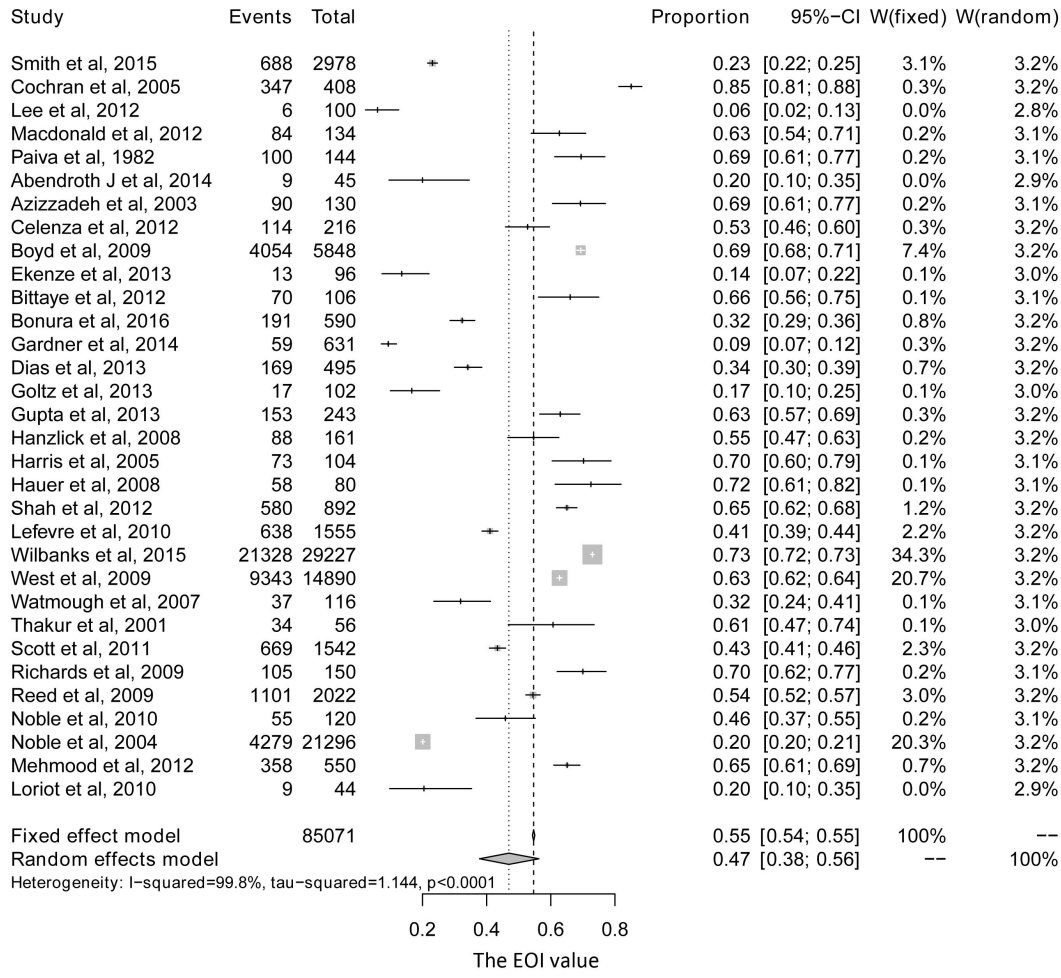


Figure S7. Forest Plot of "Career Opportunities".

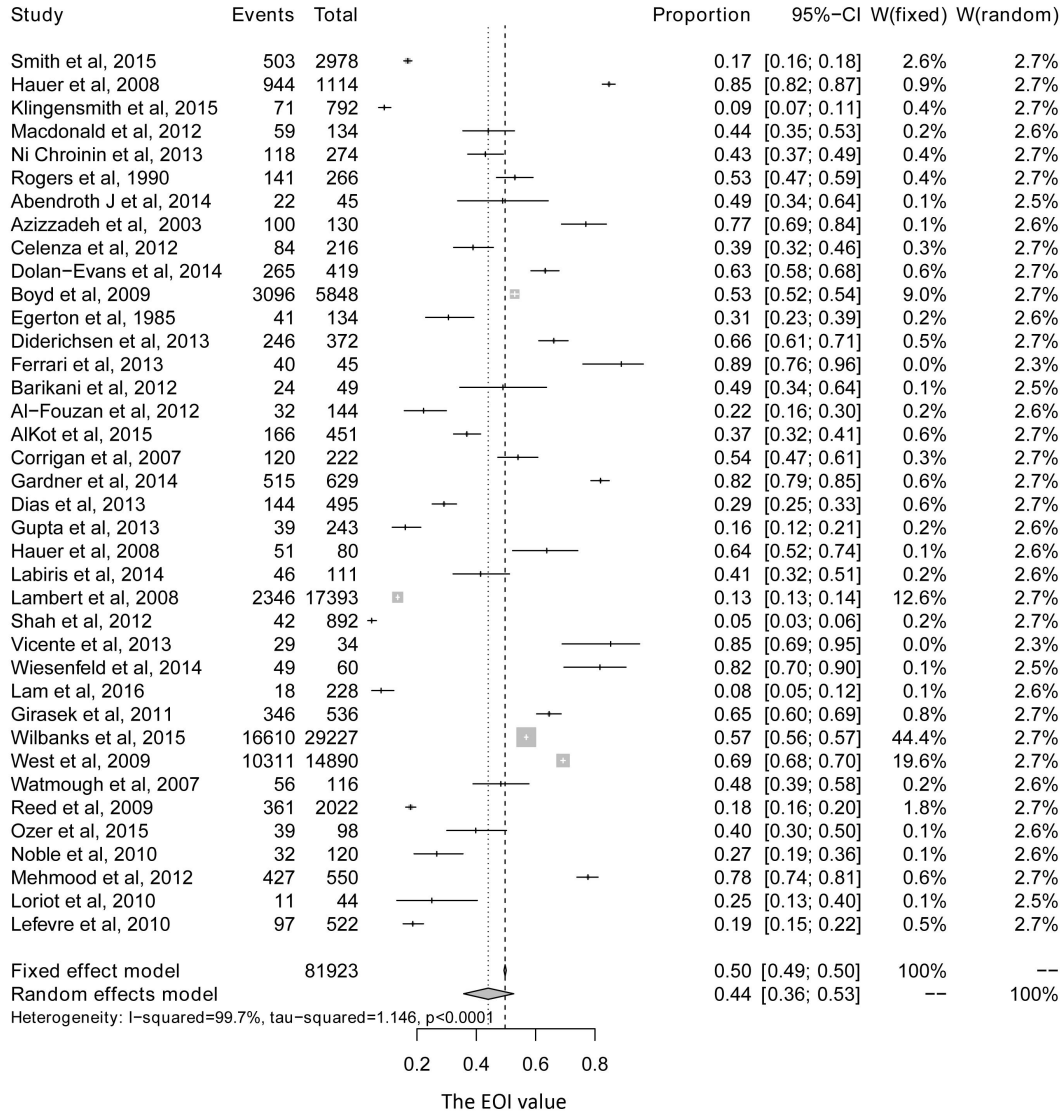


Figure S8. Forest Plot of "Workload or Working Hours".

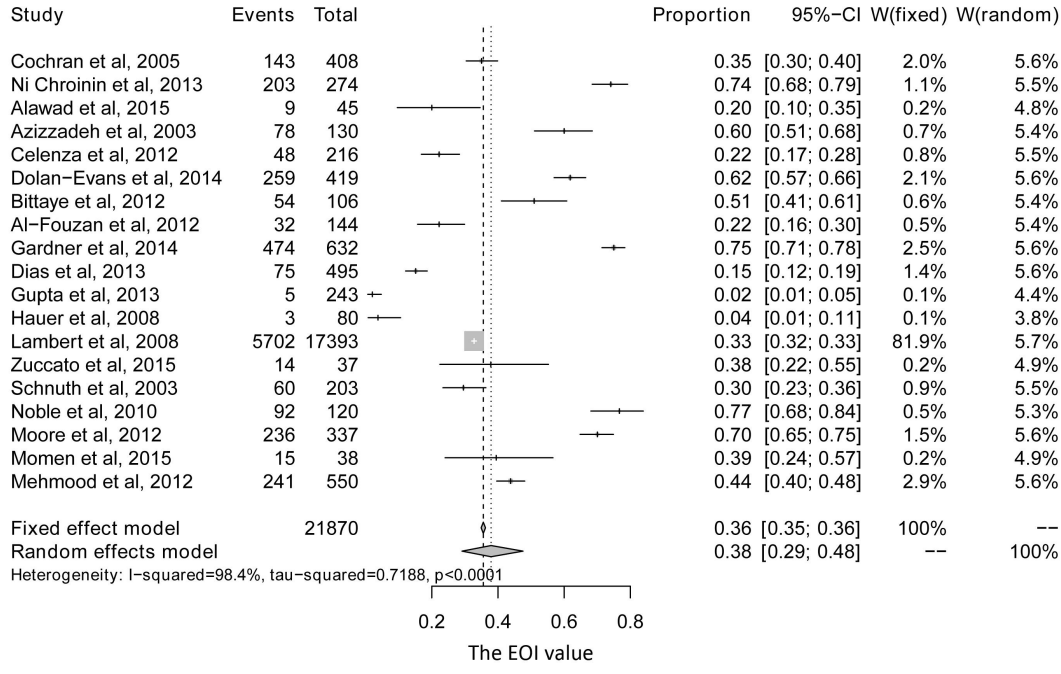


Figure S9. Forest Plot of "Income".

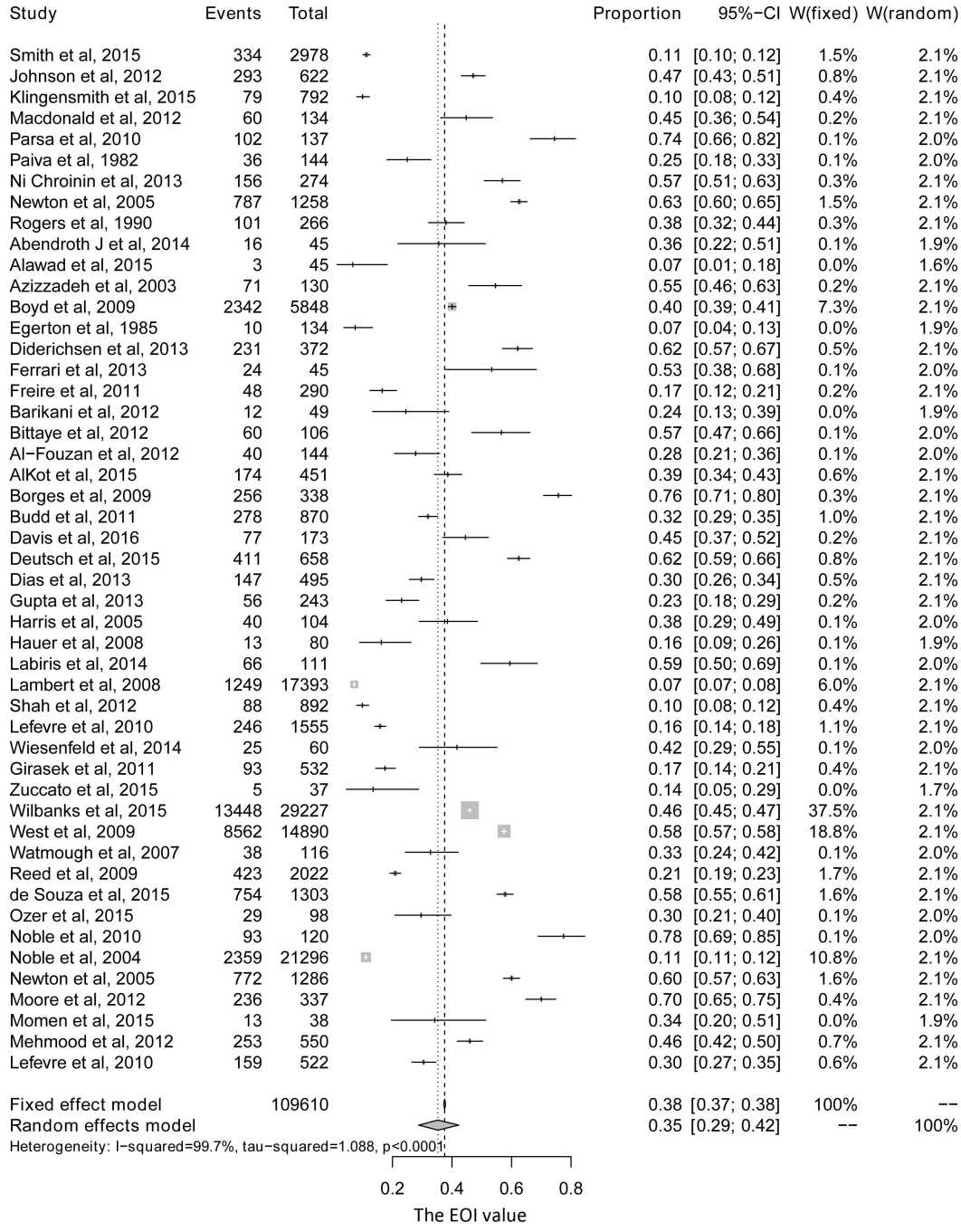


Figure S10. Forest Plot of "Length of Training".

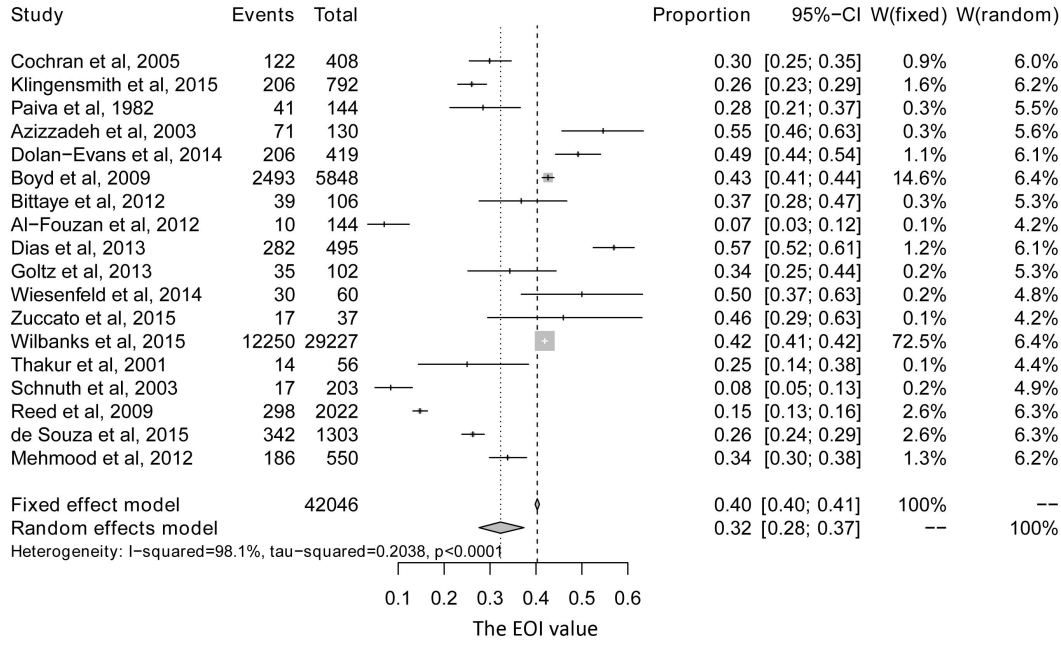


Figure S11. Forest Plot of "Prestige".

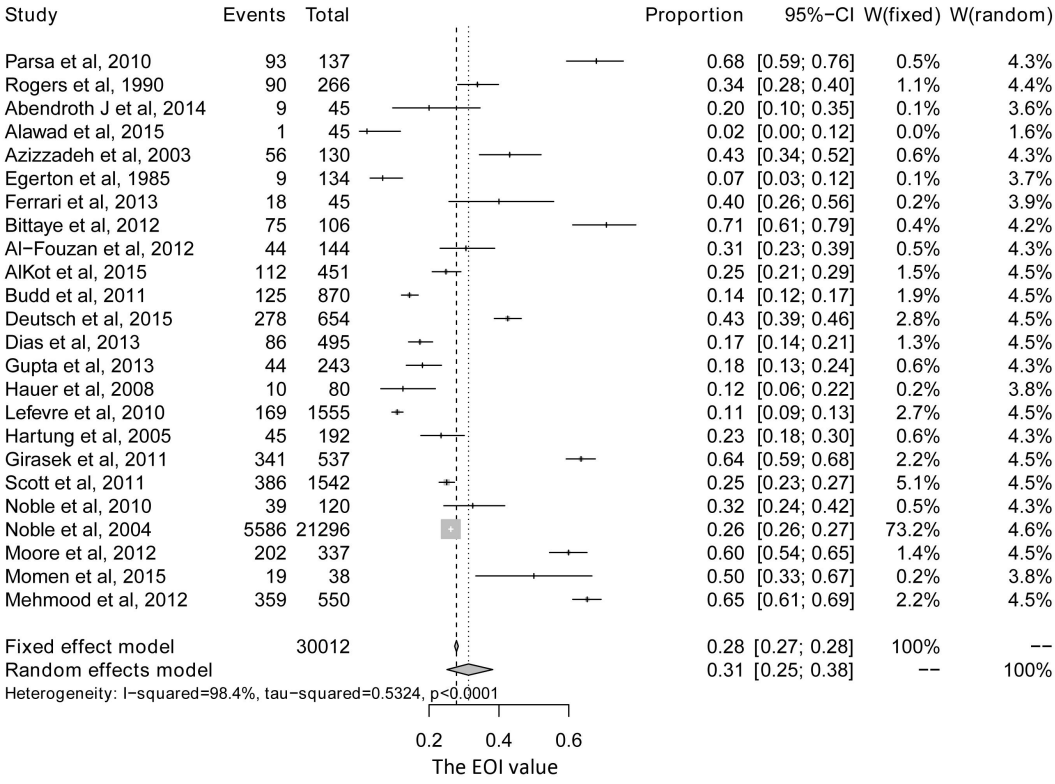


Figure S12. Forest Plot of "Advice from Others".

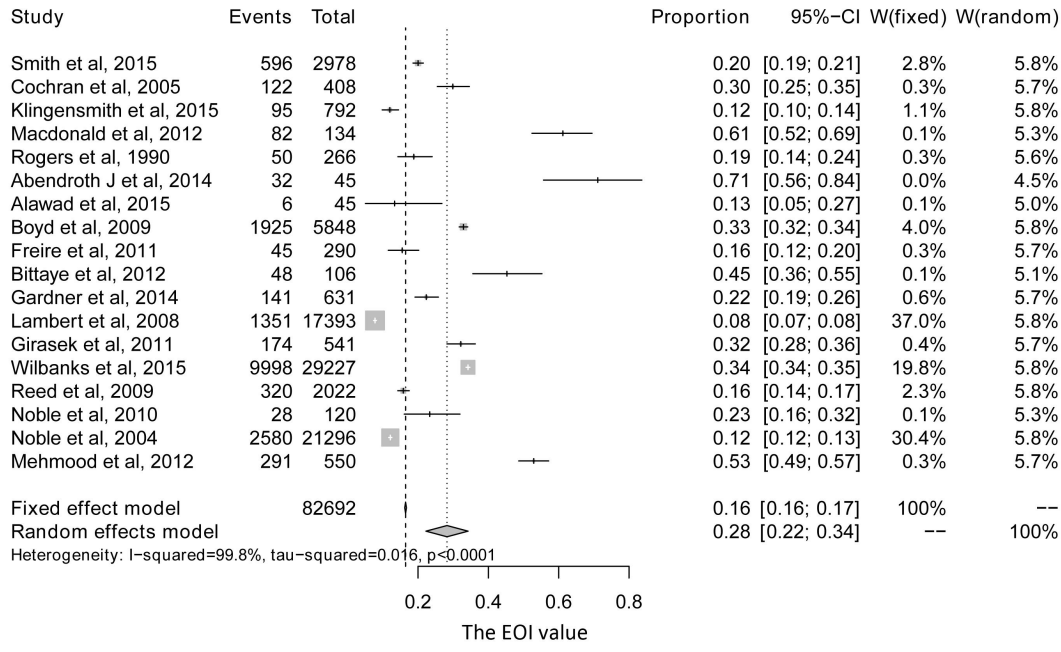


Figure S13. Forest Plot of "Student Debt".

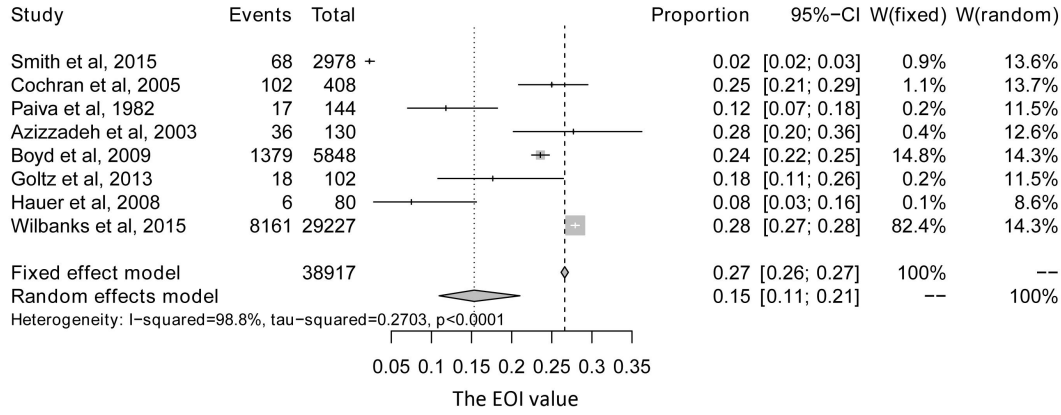
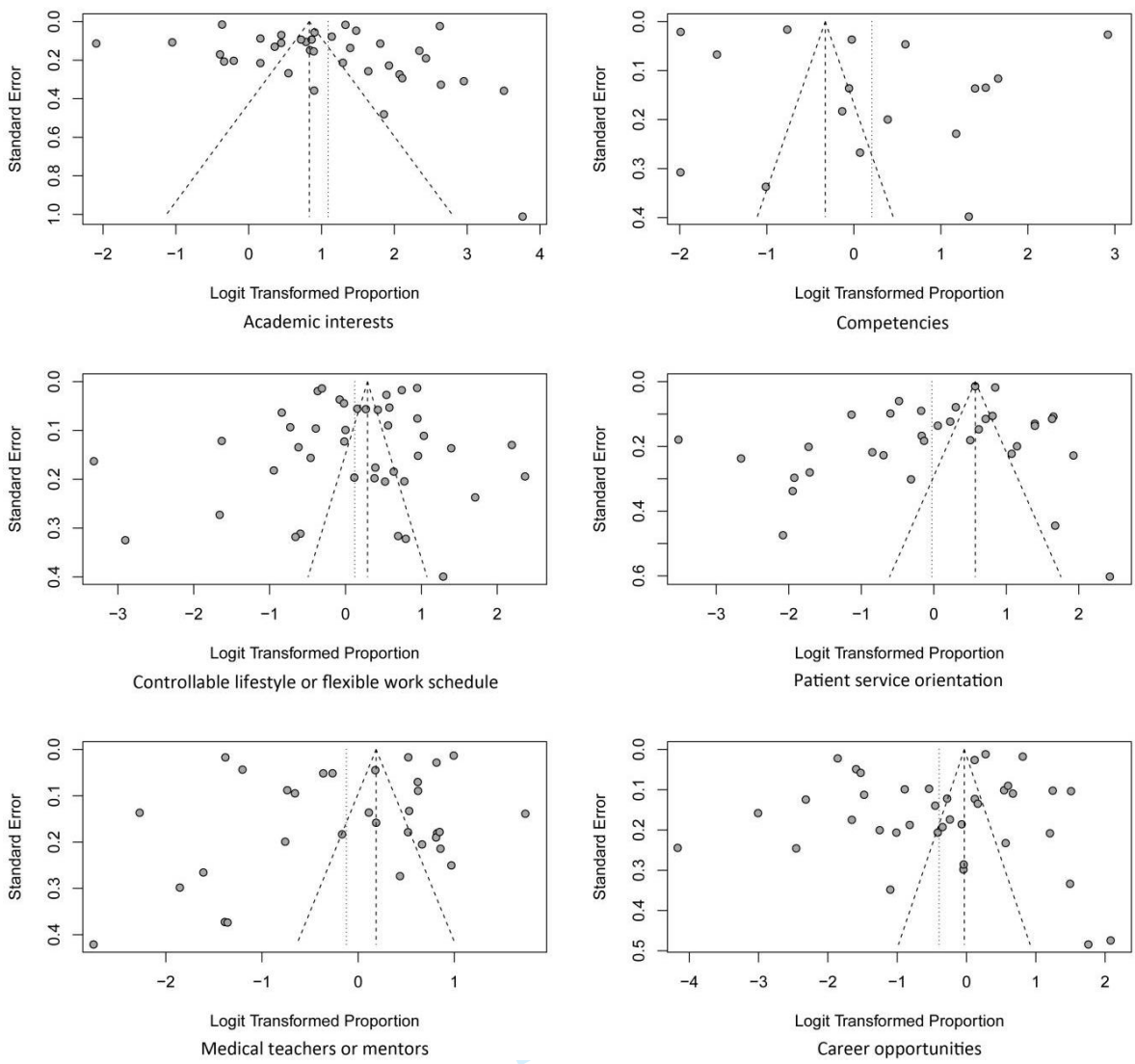
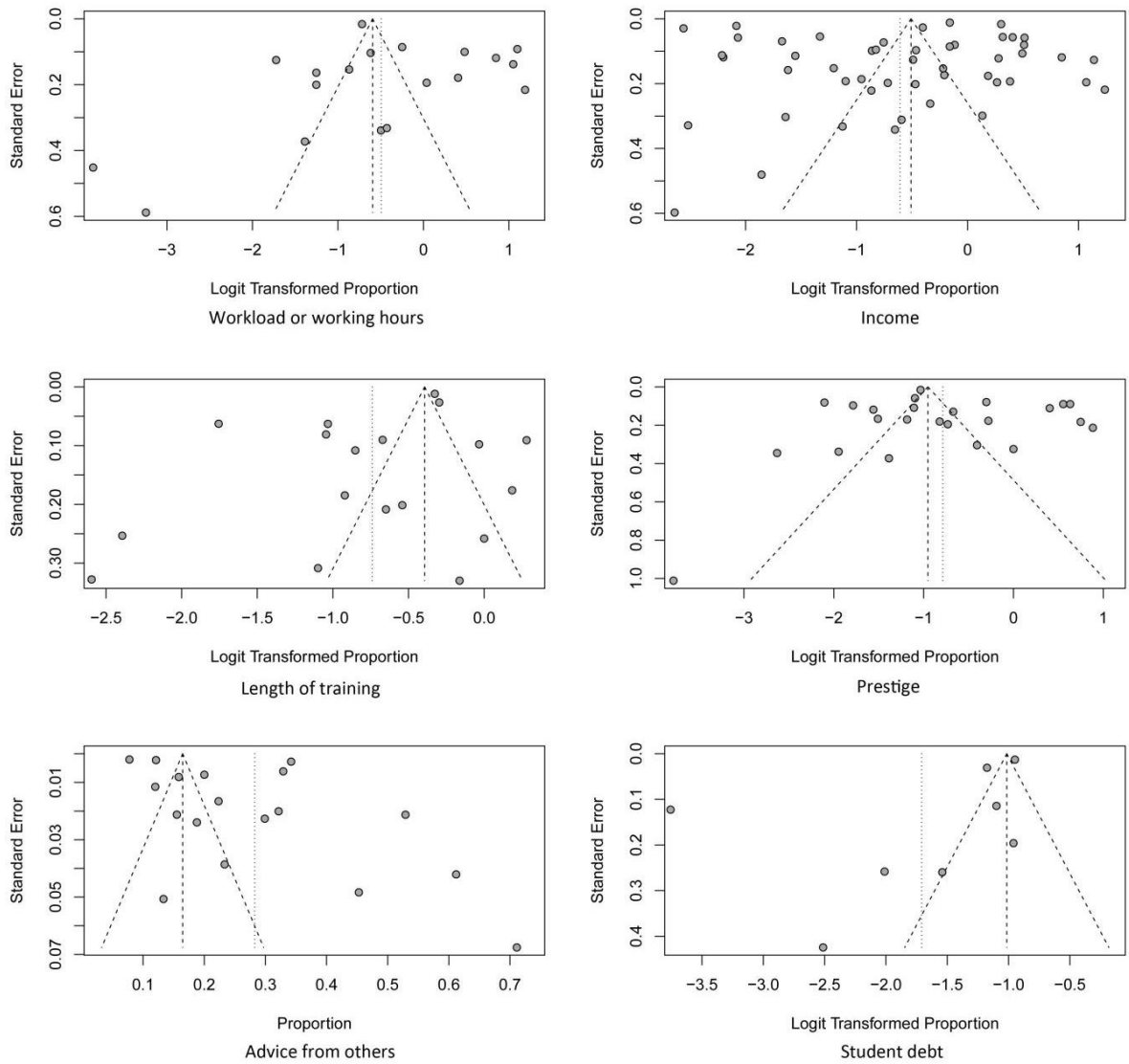


Figure S14. Funnel Plots of the Publication Bias Testing of the 12 Factors.





PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5, 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7-8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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Title Page

Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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ABSTRACT

Objective To characterize the contributing factors that affect medical students' subspecialty choice and to estimate the extent of influence of individual factors on the students' decision-making process.

Design Systematic review and meta-analysis.

Methods A systematic search of the Cochrane Library, ERIC, Web of Science, CNKI and PubMed databases was conducted for studies published between January 1977 and June 2018. Information concerning study characteristics, influential factors, and the extent of their influence (EOI) was extracted independently by two trained investigators. EOI is the percentage level that describes how much each of the factors influenced students' choice of subspecialty. The estimates were pooled using a random-effects meta-analysis model due to the between-study heterogeneity.

Results Data were extracted from 75 studies (882,209 individuals). Overall, the factors influencing medical students' choice of subspecialty training mainly included academic interests (75.29%), competencies (55.15%), controllable lifestyles or flexible work schedules (53.00%), patient service orientation (50.04%), medical teachers or mentors (46.93%), career opportunities (44.00%), workload or working hours (37.99%), income (34.70%), length of training (32.30%), prestige (31.17%), advice from others (28.24%), and student debt (15.33%), with significant between-study heterogeneity (P<0.0001). Subgroup analyses revealed that the EOI of academic interests was higher in developed countries than that in developing countries (79.66% [95% confidence interval (CI), 70.73%; 86.39%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). The EOI value of prestige was lower in

developed countries than that in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01).

Conclusions This systematic review and meta-analysis provided a quantitative evaluation of the top 12 influencing factors associated with medical students' choice of subspecialty. Our findings provide the basis for the development of specific, effective strategies to optimize the distribution of physicians among different departments by modifying these influencing factors.

Systematic review registration PROSPERO CRD42017053781.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study that provide a systematic estimate of the factors associated with medical students' subspecialty choices.
- A large number of studies conducted in varied populations have been included.
- The differences in the characteristics of country, survey years, specialty, the type of data used and sample size across studies represent a major limitation of our study.

KEYWORDS Medical students, career choice, meta-analysis

Introduction

Because of the population aging, increased workload on doctors through increased number of consultations and in managing patients with multi-morbidity, the demand for physicians continues to increase; however, an imbalance in the supply of physicians in different subspecialties has become a growing concern in both developed and developing countries. [1-5] Some specialties and subspecialties, such as family medicine and palliative medicine,[6 7] are experiencing a desperate shortage of physicians, whereas other specialties and subspecialties, such as cardiology, ophthalmology and ear, nose and throat (ENT) surgery, require several years of training before admission due to intense competition.[8 9]

Specialty choice is the product of a complex interconnection of student expectation, department expectation, and competition for available spots, and student choice is where the choice begins.[10] Previous studies have suggested that medical students' choice of subspecialty is essential to the maintenance of an adequate medical workforce and a balanced development of the medical system.[11 12] However, the influencing factors underlying students' subspecialty choice have not been systemically reviewed. Recent changes in the training and practice environment may influence medical students' career choice.[13] Additionally, the variability in preferences over time and in students' attitudes towards career choices can further complicate this assessment. For example, a study in the UK indicated that half of the medical students made a definitive subspecialty choice during their first year of medical school.[14] However, students were prone to changing their subspecialty preference during medical school and internship.[15] Notably, students may also reject certain subspecialties during their medical school training, even those they have previously seriously considered.[16] Therefore, identifying the factors that influence

students' choice of subspecialty will enable a better understanding of the current shortage/overload of physicians in specific fields and contribute to policy-building and decision-making to improve the training and recruitment of students in the future. We thus conducted a systematic review and a meta-analysis to investigate the influencing factors and the extent of their influence on the choice of subspecialty training among medical students. More specifically, we focused on the following questions. First, can we gain a better understanding of students' preferences for medical specialty according to the primary influencing factor? Second, do the subgroups according to world region and survey years examined in this study differ significantly with regard to the weight that students place on the identified influencing factor?

Methods

We developed a review protocol (registration number: PROSPERO CRD42017053781) prior to commencing the study. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was used to ensure the reporting quality of this review **(Fig. S1)**.[17]

Search Strategy and Study Eligibility

We performed a literature search in June 2018 using the Cochrane Library, Medline, Web of Science, CNKI and ERIC databases without language restrictions. Articles were screened by title, abstract and reference list, and by correspondence with study investigators Potentially relevant papers were first identified by reviewing the titles and abstracts, and the full text of each retrieved article was then assessed. A detailed example of search strategy for Medline/PubMed is shown in **Methods S1**. Studies were included if they reported data on medical students, were published in peer-reviewed journals, and used a validated method to assess the extent of a factor's

influence on the choice of subspecialty, such as pediatric gastroenterology and vascular surgery, or its corresponding specialty, such as pediatrics and surgery. Because of the differences between medical education systems in the world, the medical students we recruited includes the student in medical school, internship, residency training and fellowship, containing the students who about to make a specialty choice and students who has just made a specialty choice. A guide to medical specialty, available at https://www.abms.org/member-boards/specialty-subspecialty-certificates/, were used to identify the medical specialty and subspecialty of our research. We also conducted an additional search using OpenGrey. However, no additional articles were further included. All searches were performed using Google chrome (version 54.0.2840).

Data Extraction and Quality Assessment

The following information was independently extracted from each article by 2 trained investigators (Y.Y. and J.L.) using a standardized form: study design, geographic location, years of survey, journal, sample size, average age of the participants, the number and percentage of male participants, and the influencing factors and the extent of their influence. A third investigator was consulted if disagreements occurred. Each study may involve one or several influencing factors. An 11-item checklist which was recommended by Agency for Healthcare Research and Quality (AHRQ), used for cross-sectional studies, available at https://www.ncbi.nlm.nih.gov/books/NBK35156/, were used to assess the quality of the studies. All discrepancies were resolved via discussion and consensus.

Statistical Analysis

As considerable heterogeneity was expected because of the multiple sources of variances, a random effects meta-analysis model was used to estimate the influencing

factors and the extent of their influence.[18] Between-study heterogeneity was assessed using the I^2 statistic, which was calculated to describe the percentage of total variation caused by heterogeneity across studies, with ≥50% indicating considerable heterogeneity. [19] [20] Potential sources of heterogeneity were identified using meta-regression.[21] Subgroup analyses were performed for each factor in the studies in developed countries vs. developing countries and studies conducted before 2010 vs. after 2010. The EOI value of competencies in developing countries was not statistically significant (81.21% [95% CI, 75.27%; 86.51%], P=0.1436), and no studies on the influence of student debt in developing countries were found. The Q-test based on the analysis of variance was used to compare the subgroups, with a significance threshold of 5%.[22] The influence of individual studies on the overall EOI value was explored by serially excluding each study in a sensitivity analysis. Publication bias was investigated using a funnel plot test and Egger's test.[23] [24] All analyses were performed using R (version 3.3.1, The R Foundation, Vienna, Austria). The statistical tests were 2-sided with a significance threshold of P<0.05.

Results

Study Characteristics

Seventy-five cross-sectional studies involving a total of 882,209 individuals that published between January 1977 and May 2018 were included in the present research **(Table 1).** Thirty-four studies were conducted in North America, 24 in Europe, 7 in Asia, 5 in Oceania, 3 in Africa, and 2 in South America. The median number of participants per study was 243 (range 37-29,227). Fourteen studies included students who had already selected subspecialties, whereas 61 did not. The influencing factors were ranked according to the frequency of occurrence and each factor was identified when at least 5 papers were available describing it. The influencing factors for

subspecialty choice were then classified according to 17 aspects, including academic interests, controllable lifestyle or flexible work schedule (defined as flexibility that allows physicians to control the number of hours devoted to practicing the specialty), competencies, patient service orientation, medical teachers or mentors, career opportunities, workload or working hours (characterized by the physician's time spent on professional responsibilities), income, prestige, length of training, advice from others (advice from family, friends, and other students), student debt, experience with the subject, working environment, personality, gender and job security. Personality and gender are common factors that affect the choice of subspecialty among medical students, but most of the relevant literature has not reported on the extent of these factors' influence. Moreover, the funnel plots were clearly asymmetrical with regard to experience with the subject, the working environment and job variety, indicating the existence of publication bias. Thus, the analysis of the remaining 12 influencing factors were shown in this paper. Studies assessed for influencing factors using questionnaires validated to medical students asking the extent of certain factors the studies investigated. Quality assessment scores for the included studies are listed in **Table 1**. None of the studies received a point for the second AHRQ Quality Indicator, which requires studies to list the inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications, since no comparison studies were referenced in the analyzed articles. For the remaining 10 criteria, 6 studies received 9 points, 8 studies received 8 points, 17 studies received 7 points, 33 studies received 6 points, 9 studies received 5 points and 2 studies received 4 points (scores for individual studies are presented in **Table S1**).

Primary Analysis

A meta-analysis was performed on the 12 influencing factors **(Table 2)**: academic interests **(Fig. S2)**, competencies **(Fig. S3)**, controllable lifestyle or flexible work schedule **(Fig. S4)**, patient service orientation **(Fig. S5)**, medical teachers or mentors **(Fig. S6)**, career opportunities **(Fig. S7)**, workload or working hours **(Fig. S8)**, income **(Fig. S9)**, length of training **(Fig. S10)**, prestige **(Fig. S11)**, advice from others **(Fig. S12)** and student debt **(Fig. S13)**. All the factors were significant with evidence of between-study heterogeneity (P<0.0001). A sensitivity analysis, in which the meta-analysis was serially repeated after the exclusion of each study, demonstrated that no individual study affected the overall extent of a factor's influence.

Meta-regression and Subgroup Analysis

Using common instructions when at least 5 studies were available and at least 2 studies were in each comparator subgroup, four categorical covariates were identified as potential sources of heterogeneity by examining the studies conducted in the United States (US) vs. the studies conducted in other countries, the studies conducted before 2010 vs. those conducted after 2010, the studies concerning subspecialty only vs. those that were not specific to a subspecialty, and the studies with a sample size <200 vs. the studies with a sample size ≥200 **(Table 3).** Some of the heterogeneities observed among the 12 factors can be partially explained by country, survey years, specialty and sample size.

EOI values were further analyzed by subgroup **(Table S2)** according to world region **(Fig. 1)** and survey year **(Fig. 2).** The EOI value of academic interests in developed countries was higher than that in developing countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). Conversely, a lower EOI value of prestige was found in studies conducted in developed countries

than in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01). No statistically significant subgroup differences in the EOI values of the other influencing factors were noted between developed countries and developing countries**.** In addition, no statistically significant differences in the EOI values of the influencing factors were observed when subgroup analysis was performed by survey year.

Assessment of Publication Bias

We generated a funnel plot with proportion as the abscissa and standard error as the ordinate. A visual inspection of the funnel plots revealed minimal asymmetry among the various influencing factors **(Fig. S14)**, and the results were concentrated in the narrow upper part of the graph. However, there was evidence of small study effect in the meta-analysis of "patient service orientation" (Egger's test P=0.02).

Discussion

Implications

This systematic review and meta-analysis involved 75 studies with 882,209 medical students. Twelve influencing factors were analyzed. These factors can be classified into two categories: economic factors and non-economic factors. We found that the EOI of the economic factors, including income (34.70%) and student debt (15.33%), may not depend on the region's level of economic development. However, income remained a major influencing factor in the process of choosing a specialty or subspecialty. In the US, 15% of full-time family medicine physicians earned less than $100,000 in 2004, which is significantly less than the income earned by invasive cardiologists (median income=$427,815), neurosurgeons (median income=$211,094), and orthopedists (median income=$335,646).[25] This economic inequality made family medicine less attractive to medical school graduates.[26] Benefits such as health

insurance and tuition reimbursement have been shown to be the most common economic incentives used to attract applicants.[27]

The non-economic factors can be divided into individual factors, specialty-related factors and others. First, individual factors, including academic interest and competencies, have a considerable impact on students' subspecialty choice, with EOI values of 75.29% and 55.15%, respectively. In addition, in the subgroup analysis, although academic interests were less influential in developing countries than in developed countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02), they were still the most influential of the 12 factors regardless of regional economic level. These findings indicate that subspecialties with a shortage of manpower may attract more students by increasing students' interests and improving the quality of education. Previous studies indicated that early specialty exposure in medical education may arouse students' academic interest and improve their clinical competence.[26 28] For example, an elective extracurricular program designed to facilitate early contact with family medicine physicians was found to significantly improve students' interest and clinical skills, especially communication skills, in family medicine.[29] Furthermore, dispelling myths and espousing the positive aspects of a discipline may provide a better understanding of certain specialties; this approach could also be effective in increasing students' academic interest.[30] For instance, family medicine is often considered a discipline that requires less professional skills and knowledge. This misconception demotivates students from choosing family medicine as their future career specialty, and this trend may eventually lead to a shortage of family physicians.[30] Eliminating such prejudices may help students pay greater attention to the areas in short supply and restore their interests in other specialties.

Second, the specialty-related factors included controllable lifestyle/flexible work schedule (EOI of 53.00%), career opportunities (EOI of 44.00%), workload (EOI of 37.99%) and training length (EOI of 32.30%). Of these factors, lifestyle varied between different areas. Additionally, although certain specialties, such as general surgery, seem to have an adequate number of surgeons on a per capita basis in the US, there is still a poor geographic distribution within the surgical workforce according to the type of surgical practice.[31] The inflexible lifestyle is a common reason that students perceive surgery to be less attractive.[31] Reorganization of expected work hours within shared practices and the increased use of physician extenders and technologies such as electronic medical records may give physicians more flexibility in work schedules.[32] Moreover, providing promotion opportunities and shortening the length of training are possible strategies to recruit new staff in subspecialties that require a long period of post-graduate residency training, such as neurosurgery.[33]

Finally, other factors such as service orientation (EOI of 50.74%), medical teachers or mentors (EOI of 46.93%), prestige (EOI of 34.68%), and advice from others (EOI of 28.24%) also contribute to the decision-making process of medical students. For example, the desire to care for patients with end-stage diseases contributed to the decision to enter palliative medicine in 86% of the medical students.[7] Additionally, exposure to mentors in a particular clinical field such as internal medicine has been strongly associated with medical students' choice of clinical field.[34] Moreover, improving the occupational prestige of areas such as family medicine, pathology, and radiology may help reshape the distribution of the workforce. [28 35 36]

In our study, several findings are especially noteworthy. First, interest was far more important than income in deciding subspecialty. In our study, interest was the top-ranked influencing factor (EOI of 75.29%) of subspecialty choice, while income

was ranked lower (EOI of 34.70%). This finding argues against the possible default belief that raising physician's wages alone could solve the uneven distribution of clinicians among subspecialties. Our findings highlight that cultivating and stimulating students' professional interests may help improve the maldistribution of medical resources in a more efficient and cost-saving manner.

Second, improving abilities in a certain subspecialty of interest can greatly affect medical students' professional choice. In our study, competencies ranked second in influence, which may reflect the impact of admission conditions on students' choice of subspecialty. Hence, to reduce the risk that students are restricted to the subspecialty of their interest due to a lack of personal skills, medical education should focus more on enhancing students' personal competencies in addition to their academic interests.

Third, balancing medical resources is a complex process in practical terms, as the influencing factors are not mutually exclusive. The shortage of physicians in certain subspecialties may increase physician workload, resulting in less time for teaching. Hence, the quality of teaching cannot be guaranteed, and students may tend to avoid choosing these subspecialties, thus worsening the imbalance in the medical workforce. Additionally, some of the 12 factors identified are not amenable to practical interventions. For example, prestige cannot be immediately increased using interventional strategies.[35] Overall, effective strategies must be multi-pronged and incorporate several different aspects, and maldistribution in the workforce should not be tackled through a simple adjustment of one influencing factor.

Interpretations of the results of this meta-analysis

Our meta-regression stratified by the study-level characteristics found that country, survey years, subspecialty and sample size may contribute to the heterogeneity

between studies. There was no significant difference in the sensitivity analysis, which indicated that the results of the meta-analysis were convincing. The funnel plots and Egger's tests revealed that most of the publication bias was small (P>0.05), except for the meta-analysis of "patient service orientation". Moreover, the majority of the studies collected in the database were from developed countries rather than developing countries.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the students involved in our study included medical students at different stages of their medical education. Students' perception about different subspecialties may change during medical training until the students applies for specialty training. For example, compared to an intern, a freshman student may place greater emphasis on income and prestige when considering a career choice.[37] A subgroup analysis stratified by the stages of medical education and a secondary meta-analysis of longitudinal studies may better reflect changes in influencing factors and the extent of their influence over time. Second, our meta-analysis summarized the data from different geographic regions around the world, and the general conclusions may not be appropriate to guide policy development in each region. Enhanced effort is needed to develop specific intervention strategies according to the specific economic level, religious beliefs, healthcare system, educational system and endemic diseases of different countries and regions. Subgroup analysis stratified by organizational and medical training factors would provide more information of the factors influencing subspecialty choice among medical students. Third, the surveys in the various studies were also conducted using different methods. Most of the questionnaires used a Likert scale. Therefore, when we converted the results to a percentage representing

the extent of a factor's influence, the Likert scale items were treated as interval data.[38-40] Consequently, there may have been differences in the conversion process. Finally, the analysis relied on aggregated published data. A multicenter prospective study would provide more accurate estimate of the influencing factors and the extent of their influence on medical students' choice of subspecialty.

Conclusion

In conclusion, this systematic review and meta-analysis provided a summary evaluation of 12 influencing factors and the extent of their influence on the choice of subspecialty training among medical students. Understanding students' attitudes toward their subspecialty decision-making process could provide the basis for developing strategies to increase the attractiveness of subspecialties experiencing a shortage of manpower, thereby balancing the distribution of medical recourses.

Contributors: Haotian Lin contributed to the conceptualizing and design of the study, and to research funding, coordinated the research and oversaw the project. Yahan Yang, Jiawei Li and Xiaohang Wu contributed to data collection and interpretation, and to data analysis. Jinghui Wang, Yi Zhu, Chuan Chen and Wangting Li contributed to the design of the study. All authors contributed to the drafting and revision of the paper and approved the final manuscript for publication. No patients or the public were involved in the development and design of this research.

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Data sharing: No additional data available.

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conduct of the study. We plan to liaise closely with patients, special interest groups, and charities in the dissemination of our results in printed and electronic media.

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Legends

Table 1. Selected Characteristics of the 75 Studies Included in this Systematic Review and Meta-analysis

Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Figure 1. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region.

Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

Supplements

Methods S1. Search strategy used in the current systematic review and meta-analysis.

Table S1. Quality Assessment of the Included Studies.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Figure S1. Flow Diagram of the Study Inclusion Process.

Figure S2. Forest Plot of "Academic Interest".

Figure S3. Forest Plot of "Competencies".

Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

Figure S5. Forest Plot of "Patient Service Orientation".

Figure S6. Forest Plot of "Medical Teachers or Mentors".

Figure S7. Forest Plot of "Career Opportunities".

Figure S8. Forest Plot of "Workload or Working Hours".

Figure S9. Forest Plot of "Income".

Figure S10. Forest Plot of "Length of Training".

Figure S11. Forest Plot of "Prestige".

Figure S12. Forest Plot of "Advice from Others".

Figure S13. Forest Plot of "Student Debt".

Figure S14. Funnel Plots of the Publication Bias Tests of the 12 Factors.

Table 1. Selected Characteristics of the 75 Studies Included in this Systematic Review and Meta-analysis

First Author, Year	Country	Survey years	Sample size	Average age	Men, No. (%)	Scores
Smith et al,[41] 2015	UK	2012	2,978	NR	NR	6
Cochran et al,[42] 2005	USA	2002	408	27.2	214 (52.45)	5
Hauer et al,[43] 2008	USA	2007	1,177	NR	NR	6
Johnson et al,[44] 2012	USA	2012	622	NR	NR	6
Kiolbassa et al,[45] 2011	Germany	2010	1,114	24.1	408 (36.62)	5
Klingensmith et al,[46] 2015	USA	2013	792	NR	539 (68.06)	6
Lee et al,[47] 2012	USA	2012	100	NR	58 (58)	7
Macdonald et al,[48] 2012	New Zealand	2011	134	NR	79 (58.96)	7
Parsa et al,[37] 2010	Iran	2006-2007	137	27.34	49 (35.77)	7
Paiva et al,[49] 1982	USA	1982	144	NR	NR	6
Ni Chroinin et al,[50] 2013	UK	2009-2011	274	NR	112 (40.89)	7
Newton et al,[32] 2005	USA	1998-2004	1,258	NR	642 (51.03)	8
Rogers et al,[51] 1990	USA	1989	266	NR	205 (77.07)	6
Abendroth J et al,[52] 2014	Germany	2007-2012	45	NR	14 (31)	7
Alawad et al,[53] 2015	USA	2010-2011	45	NR	36 (80)	8
Azizzadeh et al,[54] 2003	USA	2002	130	NR	NR	6
Celenza et al,[55] 2012	Australia	2009	216	NR	121 (56.02)	8
Dolan-Evans et al,[56] 2014	Australia	2013	419	NR	215 (51.31)	8
Boyd et al,[57] 2009	USA	2005-2006	5,848	NR	2,982 (50.99)	8
Egerton et al,[58] 1985	Ireland	1977-1981	134	30	82 (61.19)	6
Diderichsen et al,[59] 2013	Sweden	2006-2009	372	27	157 (42.20)	6
Ferrari et al,[60] 2013	Italy, UK	2009-2011	45	25	NR	9
Freire et al,[61] 2011	Brazil	2006-2008	290	23	102 (35.17)	7
Buddeberg-Fischer et al,[62] 2006	Switzerland	2001-2003	522	31.1	241 (46.17)	9
Dorsey et al,[63] 2005	USA	2003	11,029	NR	4,964 (45.01)	6
Ekenze et al,[64] 2013	Nigeria	2009-2010	96	25.9	NR	7
Barikani et al,[65] 2012	Australia	2008-2009	49	21.7	NR	6
Bittaye et al,[66] 2012	Gambia	2011	106	24.1	48 (45.28)	6
Bonura et al,[67] 2016	USA	2015	590	NR	321 (54.40)	9
Al-Fouzan et al,[68] 2012	Kuwait	2011-2012	144	NR	NR	7
AlKot et al,[69] 2015	Egypt	2013	451	21.8	NR	7
Borges et al,[70] 2009	USA	2001-2005	341	NR	NR	5
Budd et al,[71] 2011	UK	2011	870	22	NR	7
Corrigan et al,[72] 2007	Ireland	2007	222	NR	142 (63.96)	7
Davis et al,[73] 2016	UK	2016	173	NR	76 (43.93)	7
Deutsch et al,[74] 2015	Germany	2011	659	27.9	NR	8
Gardner et al,[75] 2014	Australia	1993-2005	631	NR	NR	7
Dias et al,[76] 2013	UK	2013	495	NR	438 (88.48)	5
Goltz et al,[77] 2013	USA	2012	102	24.5	34 (33.33)	6
Gupta et al,[78] 2013	India	2013	243	NR	179 (73.36)	6

Hanzlick et al,[79] 2008	USA	2006	161	NR	NR	6
Harris et al,[80] 2005	USA	1991-2002	104	NR	53 (50.96)	6
Hauer et al,[81] 2008	USA	2008	80	NR	NR	6
Labiris et al,[82] 2014	Greece	2014	111	23.6	55 (49.54)	6
Lambert et al,[83] 2008	UK	2007	17,393	NR	NR	6
Shah et al,[84] 2012	USA	2011	892	NR	NR	6
Lefevre et al,[85] 2010	USA	2008	1,555	NR	589 (37.88)	6
Vicente et al,[86] 2013	Chile	2013	30	NR	NR	6
Wiesenfeld et al,[87] 2014	Canada	2013	60	NR	NR	7
Lam et al,[88] 2016	Hong Kong	2015	228	23	NR	9
Hartung et al,[89] 2005	USA	2004	192	20.59	74 (38.54)	4
Girasek et al,[90] 2011	Hungary	2011	536	NR	NR	5
Zuccato et al,[91] 2015	Canada	2012	37	NR	24 (65)	6
Wilbanks et al,[92] 2015	USA	2011-2013	29,227	NR	15,164 (51.99)	9
West et al,[93] 2009	USA	2005-2007	14,890	NR	8,700 (58.43)	6
Watmough et al,[94] 2007	UK	2005	116	NR	66 (56.90)	4
Thakur et al,[95] 2001	USA	2001	56	NR	53 (95)	8
Scott et al,[96] 2011	Canada	2002-2004	1,542	NR	NR	6
Schnuth et al,[97] 2003	USA	2002	203	NR	72 (53.47)	6
Richards et al,[98] 2009	UK	2009	150	NR	108 (72.00)	5
Reed et al,[99] 2009	USA	2008	2,022	NR	1,354 (66.96)	9
de Souza et al,[100] 2015	Portugal	2012	1,303	NR	NR	7
Pikoulis et al,[101] 2010	Greece	2006-2007	87	NR	NR	6
Ozer et al,[102] 2015	Turkey	2013	98	27.7	26 (26.53)	6
Noble et al,[103] 2004	Canada	2004	21,296	NR	NR	8
Noble et al,[104] 2010	Canada	2007	120	NR	NR	5
Newton et al,[105] 2005	USA	2004	1,286	NR	NR	6
Moore et al,[106] 2012	USA	2011	337	26	179 (53.12)	6
Momen et al,[107] 2015	Iran	2014-2015	38	35.6	11 (29)	6
Mehmood et al,[108] 2012	Saudi Arabia	2012	550	NR	348 (63.27)	6
Loriot et al,[109] 2010	France	2007	44	NR	17 (39)	7
Lefevre et al,[110] 2010	France	2008	522	23.8	198 (37.93)	7
Vo et al,[111] 2017	Canada	2017	90	22.5	52 (57.78)	5
Grasreiner et al,[112] 2018	Germany	2014-2016	181	24	33 (18.10)	6
Alkhannen et al,[113] 2018	Saudi Arabia	2017	436	NA	250 (57.00)	5

Footnotes: scores: quality score of the AHRQ scale.

Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Factor	No. of studies	Total no. of participants	EOI value (%)	95 CI% of EOI value		*I-square* (%)	*Tau-square*	*P*-Value
				Lower	Upper			
Academic interests	38	82,366	75.29	66.93	82.11	99.70	1.60	<0.0001
Competencies	17	76,515	55.15	33.63	74.90	99.90	3.44	<0.0001
Controllable lifestyle or flexible work schedule	44	101,001	53.00	47.90	58.03	99.50	0.45	<0.0001
Patient service orientation	37	46,572	50.04	44.65	55.43	98.70	0.41	<0.0001
Medical teachers or	32	85,071	46.93	37.77	56.30	99.80	1.14	<0.0001
Career opportunities	38	81,923	44.00	32.26	48.78	99.70	1.15	<0.0001
Workload or working hours	20	22,051	37.99	29.59	47.19	98.30	0.69	<0.0001
Income	50	109,791	34.70	28.36	41.62	99.70	1.09	<0.0001
Length of training	18	42,046	32.30	27.61	37.37	98.10	0.20	<0.0001
Prestige	26	30,629	31.17	26.32	37.69	98.30	0.52	<0.0001
Advice from others	18	82,692	28.24	22.26	34.23	99.80	0.02	<0.0001
Student debt	8	38,917	15.33	10.96	21.03	98.80	0.27	<0.0001

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Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Factor		estimate	95 CI% of estimate		*P*-Value
			Lower	Upper	
Academic interests	Country	-0.2314	-1.1575	0.6946	0.6302
	Survey years	0.3811	-0.3580	1.1202	0.2711
	Specialty	-0.4892	-1.5345	0.5562	0.4008
	Sample size	0.2362	-0.5488	1.0212	0.6537
Competencies	Country	0.6946	-1.1461	0.8938	0.8376
	Survey years	-1.0418	-2.0950	0.0114	0.0151
	Specialty	0.0904	-1.5786	1.7594	0.9398
	Sample size	-0.5720	-1.8606	0.7166	0.5823
Controllable lifestyle or flexible work schedule	Country	-0.1261	-1.1461	0.8938	0.9614
	Survey years	-0.0001	-0.4052	0.4051	0.9822
	Specialty	-0.8989	-1.4979	-0.3000	0.0035
	Sample size	-0.0518	-0.4396	0.3361	0.7203
Patient service orientation	Country	-0.6238	-1.3118	0.0642	0.0833
	Survey years	-0.0414	-0.6912	0.6083	0.8524
	Specialty	-1.5982	-2.5227	-0.6737	0.0010
	Sample size	-0.1157	-0.7473	0.5159	0.6358
Medical teachers or mentors	Country	0.7395	0.3117	1.1674	0.0007
	Survey years	0.1133	-0.3580	0.5845	0.6376
	Specialty	0.0605	-0.4441	0.5652	0.8141
	Sample size	-0.1202	-0.5567	0.3163	0.5894
Career opportunities	Country	0.1075	-0.7030	0.9179	0.5828
	Survey years	0.3284	-0.3913	1.0480	0.7546
	Specialty	-0.9292	-1.8015	-0.0570	0.0077
	Sample size	0.3654	0.1156	1.5478	0.0081
Workload or working hours	Country	-0.4535	-1.5086	0.6016	0.3981
	Survey years	0.4624	-0.5417	1.4665	0.3922
	Specialty	-0.9878	-2.1727	0.1972	0.1070
	Sample size	0.0982	-0.8589	1.0553	0.8205
Income	Country	0.1058	-0.4665	0.6781	0.7390
	Survey years	0.0999	-0.4379	0.6377	0.8774
	Specialty	-0.6457	-1.3267	0.0352	0.0480
	Sample size	0.0523	-0.4826	0.5872	0.6786
Length of training	Country	-0.1559	-1.2782	0.9664	0.7854
	Survey years	-0.2158	-1.4089	0.9772	0.7229
	Specialty	0.3959	-0.9585	1.7502	0.5667
	Sample size	0.1565	-0.6631	0.9761	0.7082
Prestige	Country	-0.3346	-1.0799	0.4106	0.3485
	Survey years	-0.4513	-1.1378	0.2352	0.0950
	Specialty	-1.0112	-1.8980	-0.1244	0.0172
	Sample size	0.0355	-0.6013	0.6723	0.5214
Advice from others	Country	-0.0097	-0.0722	0.0529	0.9328
	Survey years	-0.0861	-0.1471	-0.0251	0.0057

	Specialty	-0.2017	-0.2790	-0.1244	<0.0001
	Sample size	0.2125	0.1309	0.2941	<0.0001
	Country	2.7853	2.0544	3.5162	0.0001
Student debt	Survey years	-0.1567	-0.6707	0.3573	0.5502
	Sample size	-0.5248	-1.0108	-0.0388	0.0343

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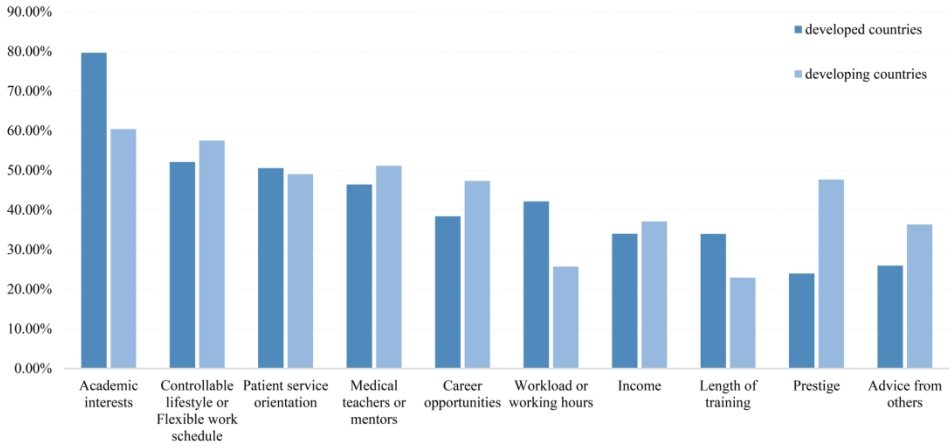


Figure 1. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region.

190x107mm (300 x 300 DPI)

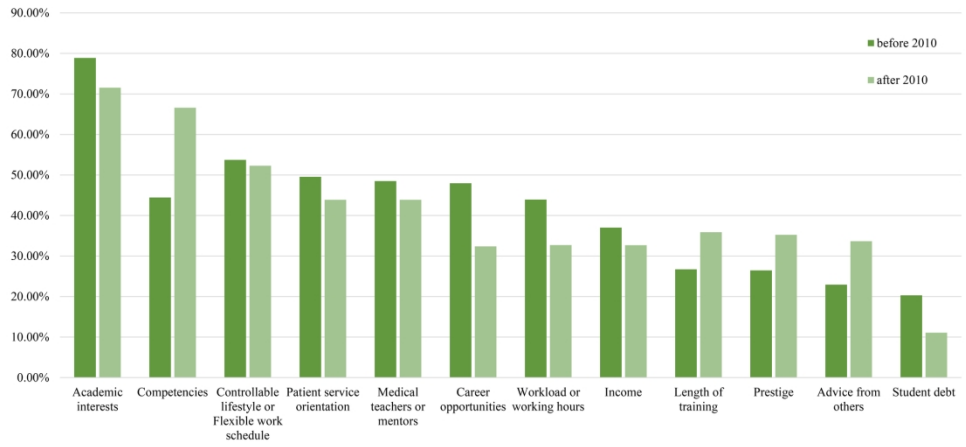


Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

190x107mm (300 x 300 DPI)

SI Methods. Search strategy used in the current systematic review and meta-analysis.

Medical Students

1. Students, Medical [Mesh]
2. Medical students
3. Medical student
4. Student, Medical
5. OR / 1 – 4

Subspecialty Choice

6. Career choices
7. Choice, Career
8. Choices career
9. Specialties
10. Sub-specialties
11. Sub-discipline
12. OR / 6 – 11

Study design

13. Cross sectional study
14. Cross sectional study [Publication Type]
15. Cross sectional study [Mesh Terms]
16. Systematic review
17. Systematic review [Publication Type]
18. Systematic review [Mesh Terms]
19. Meta-analysis [Title/Abstract]
20. Meta-analysis [Mesh Terms]
21. Meta-analysis [Publication Type]
22. OR / 12 – 21

Factors

23. Factors

Combined search

23. #5 AND #12AND #22 AND #2

Abbreviations: MeSH, Medical Subject Heading in PubMed

Table S1. Quality assessment of the included studies

	Quality assessment criteria	1	2	3	4	5	6	7	8	9	10	11	Scores
1	Smith et al,[41] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
2	Cochran et al,[42] 2005	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
3	Hauer et al,[43] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
4	Johnson et al,[44] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
5	Kiolbassa et al,[45] 2011	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
6	Klingensmith et al,[46] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
7	Lee et al,[47] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
8	Macdonald et al,[48] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
9	Parsa et al,[37] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
10	Paiva et al,[49] 1982	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
11	Ni Chroinin et al,[50] 2013	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
12	Newton et al,[32] 2005	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
13	Rogers et al,[51] 1990	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
14	Abendroth J et al,[52] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	Y	7
15	Alawad et al,[53] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	N	8
16	Azizzadeh et al,[54] 2003	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
17	Celenza et al,[55] 2012	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
18	Dolan-Evans et al,[56] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	Y	8
19	Boyd et al,[57] 2009	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
20	Egerton et al,[58] 1985	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
21	Diderichsen et al,[59] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
22	Ferrari et al,[60] 2013	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
23	Freire et al,[61] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
24	Buddeberg-Fischer et al,[62] 2006	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
25	Dorsey et al,[63] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
26	Ekenze et al,[64] 2013	Y	U	Y	Y	Y	Y	Y	N	N	Y	N	7
27	Barikani et al,[65] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
28	Bittaye et al,[66] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
39	Bonura et al,[67] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
30	Al-Fouzan et al,[68] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
31	AlKot et al,[69] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
32	Borges et al,[70] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
33	Budd et al,[71] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
34	Corrigan et al,[72] 2007	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
35	Davis et al,[73] 2016	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
36	Deutsch et al,[74] 2015	Y	U	Y	Y	Y	Y	N	Y	Y	Y	N	8
37	Gardner et al,[75] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	7
38	Dias et al,[76] 2013	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
39	Goltz et al,[77] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
40	Gupta et al,[78] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
41	Hanzlick et al,[79] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
42	Harris et al,[80] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
43	Hauer et al,[81] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
44	Labiris et al,[82] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
45	Lambert et al,[83] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
46	Shah et al,[84] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
47	Lefevre et al,[85] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
48	Vicente et al,[86] 2013	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
49	Wiesenfeld et al,[87] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
50	Lam et al,[88] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
51	Hartung et al,[89] 2005	Y	U	Y	Y	N	Y	N	N	N	N	N	4
52	Girasek et al,[90] 2011	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
53	Zuccato et al,[91] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
54	Wilbanks et al,[92] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
55	West et al,[93] 2009	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
56	Watmough et al,[94] 2007	Y	U	Y	Y	N	N	N	N	N	Y	N	4
57	Thakur et al,[95] 2001	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
58	Scott et al,[96] 2011	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
59	Schnuth et al,[97] 2003	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
60	Richards et al,[98] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
61	Reed et al,[99] 2009	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
62	de Souza et al,[100] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
63	Pikoulis et al,[101] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
64	Ozer et al,[102] 2015	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
65	Noble et al,[103] 2004	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
66	Noble et al,[104] 2010	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
67	Newton et al,[105] 2005	Y	U	Y	Y	N	Y	Y	N	N	Y	N	6
68	Moore et al,[106] 2012	Y	U	Y	Y	Y	Y	N	Y	N	N	N	6
69	Momen et al,[107] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
70	Mehmood et al,[108] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
71	Loriot et al,[109] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
72	Lefevre et al,[110] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
73	Vo et al,[111] 2017	Y	U	Y	Y	Y	N	N	N	N	Y	N	5
74	Grasreiner et al,[112] 2018	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
75	Alkhannen et al,[113] 2018	Y	U	Y	Y	N	N	Y	N	N	Y	N	5

Quality assessment criteria in detail

1. Define the source of information (survey, record review).

2. List the inclusion and exclusion criteria for the exposed and unexposed subjects (cases and controls) or refer to previous publications.

3. Indicate the time period used for identifying patients.

4. Indicate whether the subjects were consecutive if not population-based.

5. Indicate whether the evaluators of the subjective components of the study were masked to the other aspects of participants' status.

6. Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)

7. Explain any patient exclusion from the analyses.

8. Describe how confounding was assessed and/or controlled.

9. If applicable, explain how missing data were handled in the analysis.

10. Summarize the patient response rates and the completeness of the data collection.

11. Clarify what follow-up, if any, was expected and the percentage of patients with incomplete data or follow-up.

"Y": Yes; "N": No; "U": Unclear.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Factor		No. of studies	Total no. of participants	Extent of influence (%)	95 CI% of EOI value		*I-square* (%)	*P*-Value	*Q*-Value
					Lower	Upper			
Academic interest	developed	28	80,000	79.66	70.73	86.39	99.8	0.02	3.51
	developing	10	2,366	60.41	43.44	75.19	98.0		
	before 2010	29	44,174	78.88	69.04	86.22	99.7	0.40	1.21
	after 2010	9	38,192	71.54	57.66	82.27	99.6		
Competencies	before 2010	9	43,134	44.40	29.11	60.83	99.8	0.21	1.86
	after 2010	8	33,381	66.60	34.48	88.31	99.8		
Controllable lifestyle or flexible work schedule	developed	37	100,980	52.11	46.52	57.65	99.6	0.63	0.68
	developing	7	2,017	57.50	45.81	68.41	95.9		
	before 2010	22	62,945	53.72	47.48	59.84	99.4	0.97	0.05
	after 2010	22	40,056	52.29	43.51	60.93	99.2		
Patient service orientation	developed	27	44,235	50.56	44.68	56.42	98.8	0.74	0.48
	developing	10	2,337	49.02	31.62	66.67	98.1		
	before 2010	18	40,997	49.56	43.29	55.84	98.8	0.70	0.54
	after 2010	19	5,579	43.87	38.62	63.80	98.3		
Medical teachers or mentors	developed	28	84,076	46.43	36.63	56.52	99.8	0.73	0.48
	developing	4	995	51.14	33.97	68.04	95.4		
	before 2010	21	49,654	48.48	36.93	60.19	99.8	0.70	0.54
	after 2010	11	35,417	43.87	27.94	61.18	99.7		
Career opportunities	developed	31	79,867	38.41	29.61	48.04	99.8	0.60	0.74
	developing	7	2,056	47.32	30.38	64.91	98.1		
	before 2010	20	43,417	47.97	33.54	62.74	99.8	0.24	1.68
	after 2010	18	38,506	32.38	21.68	45.31	99.5		
Workload or working hours	developed	15	20,970	42.14	31.35	53.72	98.6	0.34	1.39
	developing	5	1,081	25.72	13.29	43.88	95.3		
	before 2010	9	19,456	43.93	29.43	59.54	98.8	0.41	1.21
	after 2010	11	2,595	32.70	29.43	59.54	97.4		
Income	developed	39	107,091	34.01	26.89	41.93	99.8	0.84	0.29
	developing	11	2,700	37.11	27.06	48.41	96.4		
	before 2010	25	68,714	37.01	25.95	49.62	99.8	0.41	1.18
	after 2010	25	41,077	32.67	26.04	40.07	98.9		
Length of training	developed	15	41,246	33.95	28.72	39.60	98.4	0.31	1.48
	developing	3	800	22.92	10.94	41.85	94.0		
	before 2010	7	8,811	26.72	15.89	41.29	98.9	0.28	1.59
	after 2010	11	33,234	35.87	29.67	42.59	96.9		
Prestige	developed	17	27,987	23.96	19.20	29.47	97.3	0.01	4.71
	developing	9	2,642	47.65	34.41	61.24	97.6		
	before 2010	12	25,542	26.46	20.78	33.03	96.7	0.25	1.67
	after 2010	14	5,087	35.22	24.70	47.40	98.3		
Advice from others	developed	14	81,205	25.95	19.27	32.64	99.8	0.36	1.33
	developing	4	1,487	36.34	18.91	53.77	98.1		
	before 2010	10	48,319	22.93	17.85	28.01	99.5	0.31	1.47
	after 2010	8	34,373	33.65	25.12	42.18	99.1		
Student debt	before 2010	5	6,610	20.29	15.86	25.57	81.8	0.69	0.59
	after 2010	3	32,307	11.08	1.58	49.08	99.6		

Figure S1. Flow Diagram of the Study Inclusion.

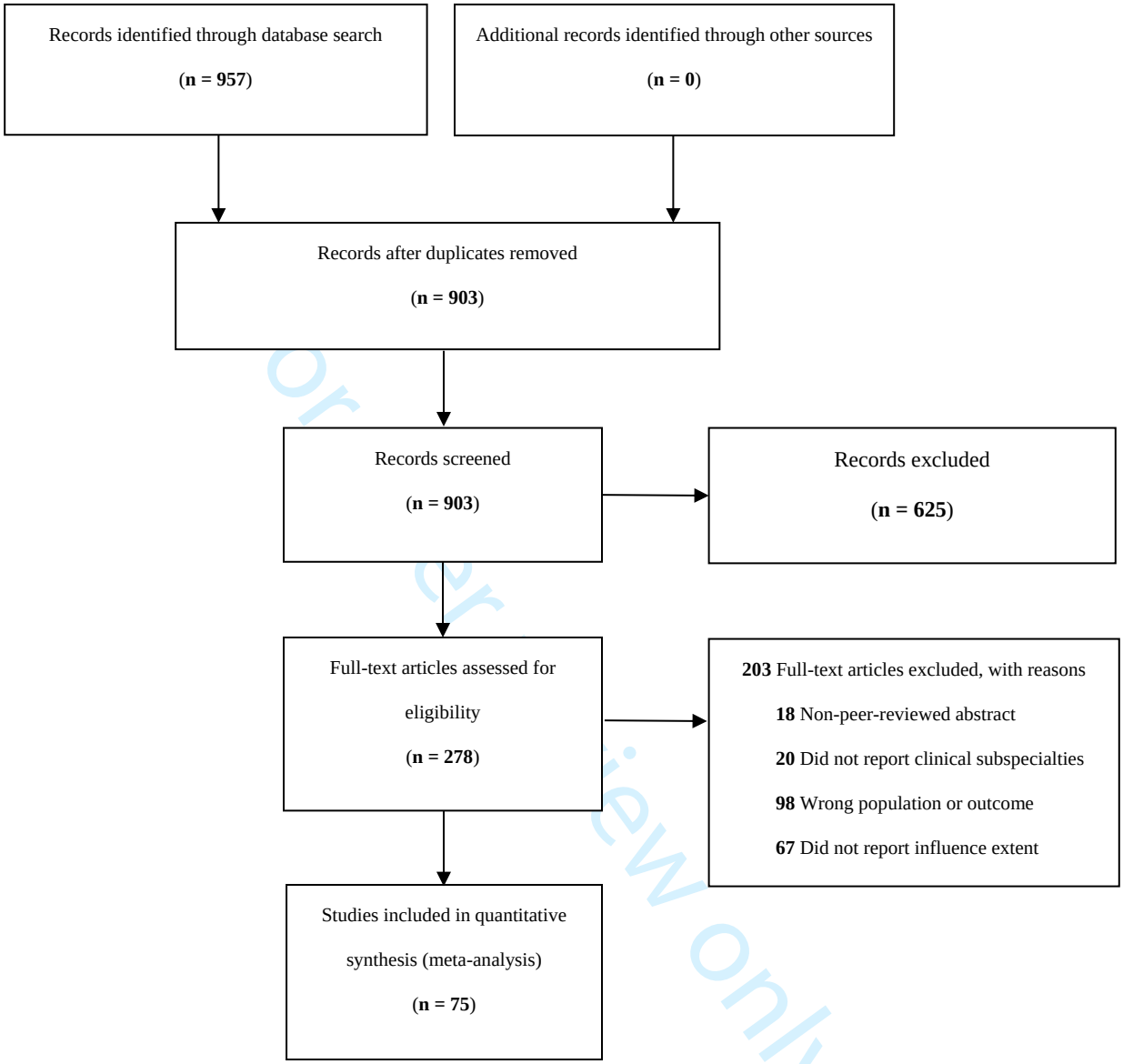


Figure S2. Forest Plot of "Academic Interest".

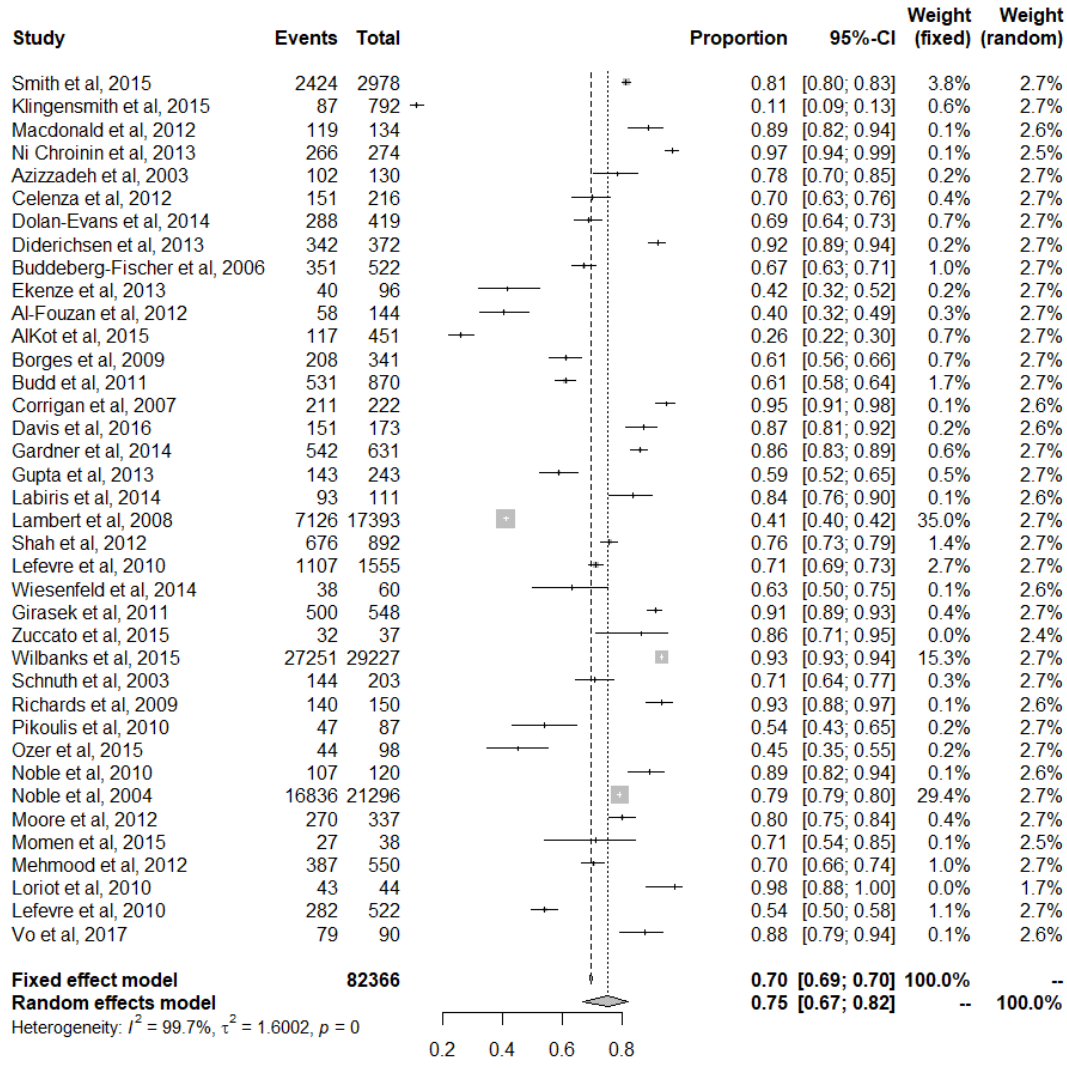


Figure S3. Forest Plot of "Competencies".

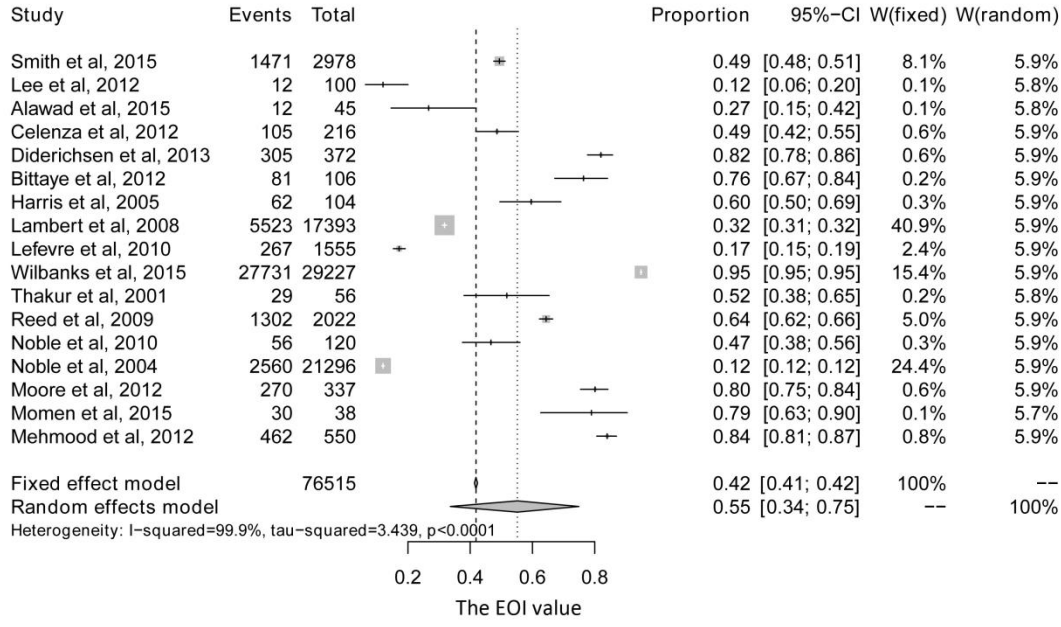


Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

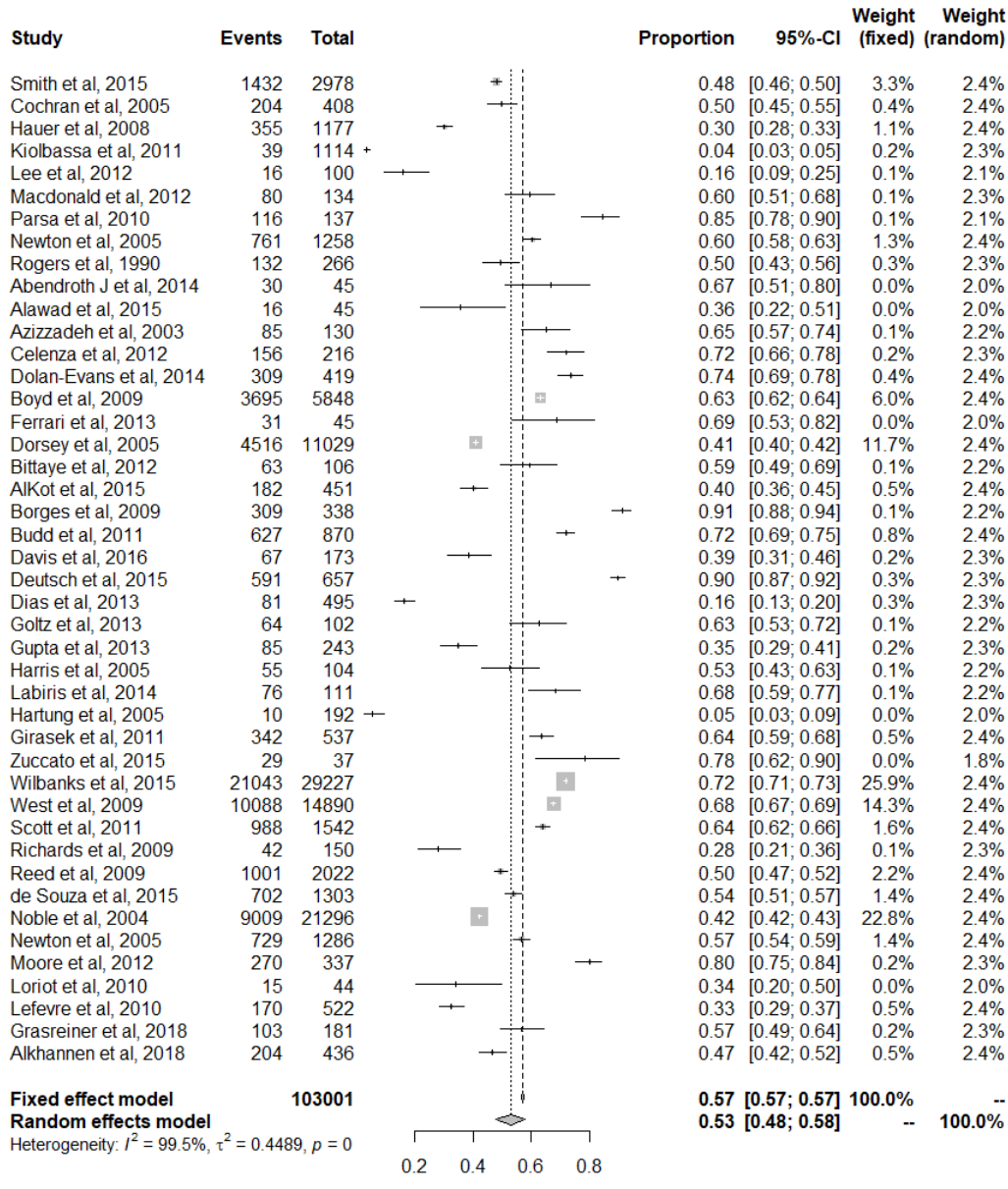


Figure S5. Forest Plot of "Patient Service Orientation".

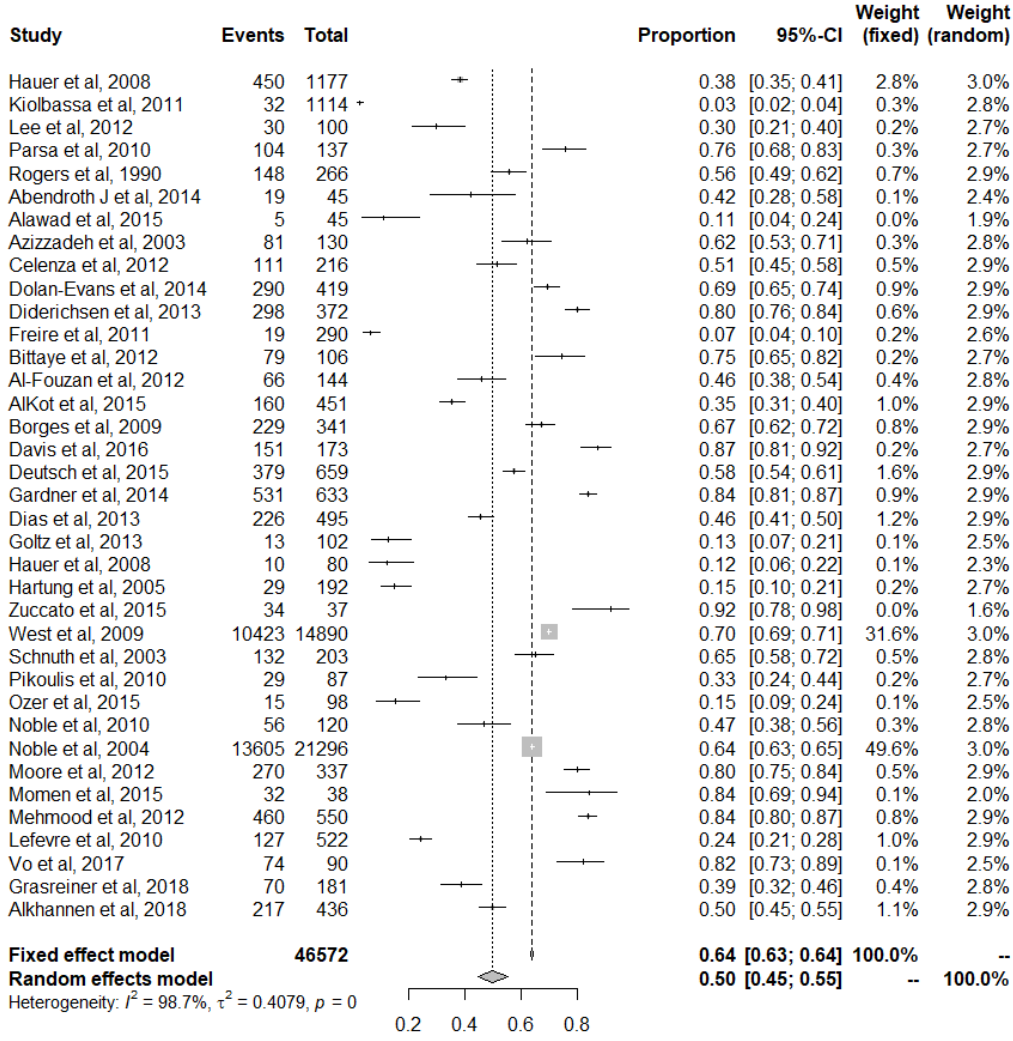


Figure S6. Forest Plot of "Medical Teachers or Mentors".

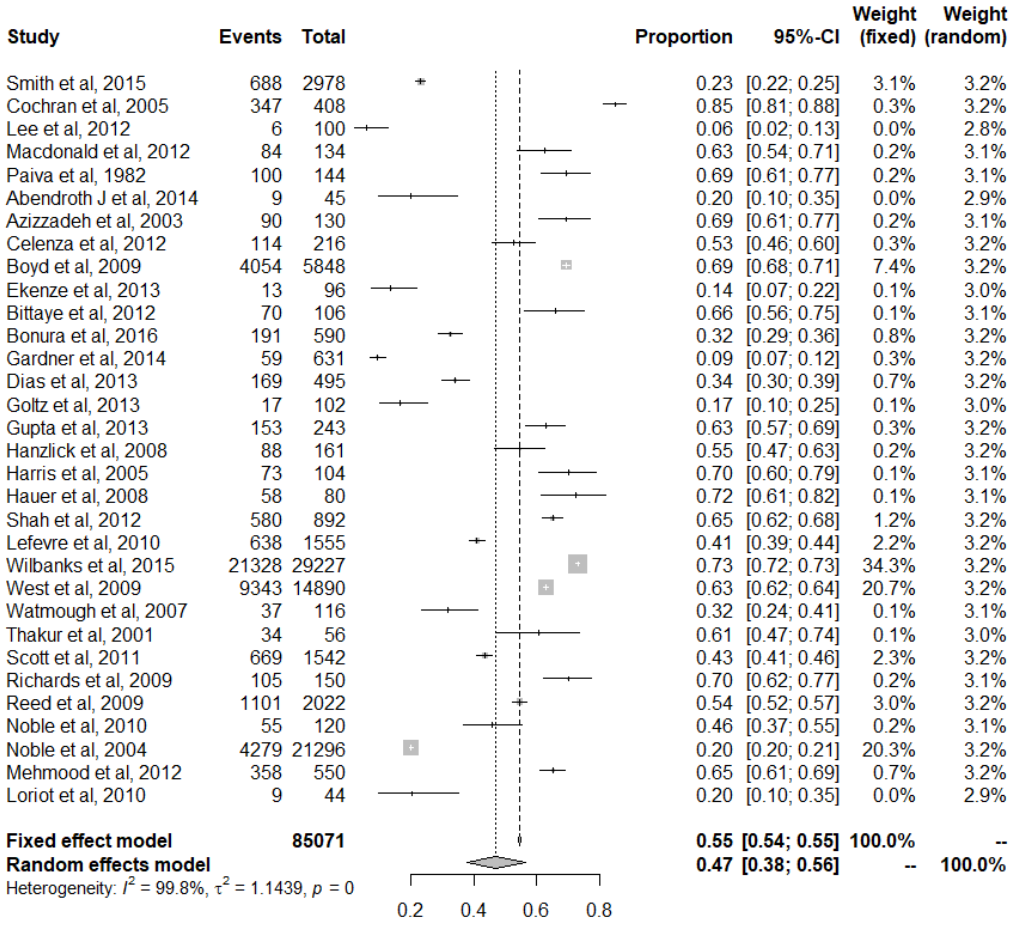


Figure S7. Forest Plot of "Career Opportunities".

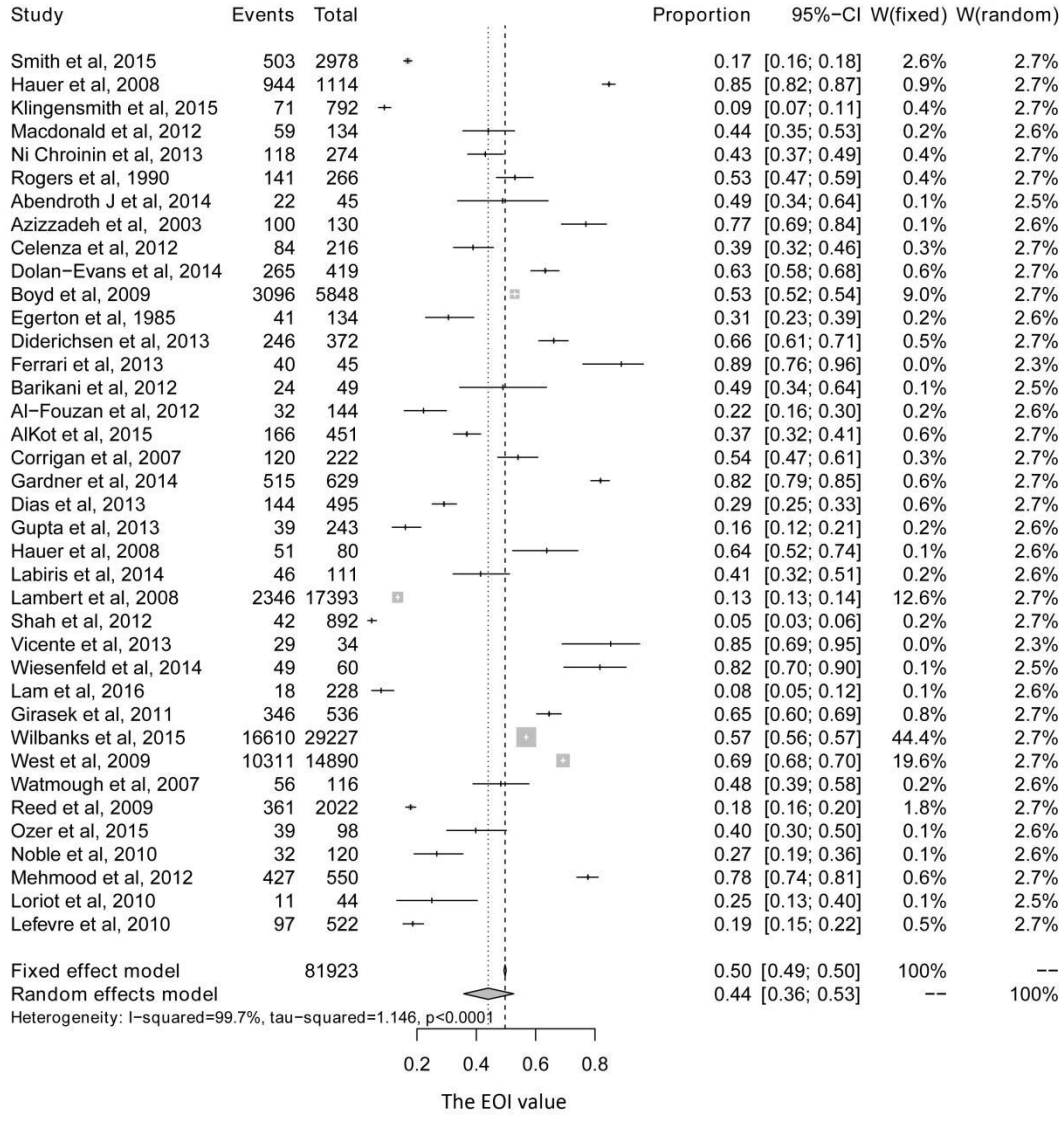


Figure S8. Forest Plot of "Workload or Working Hours".

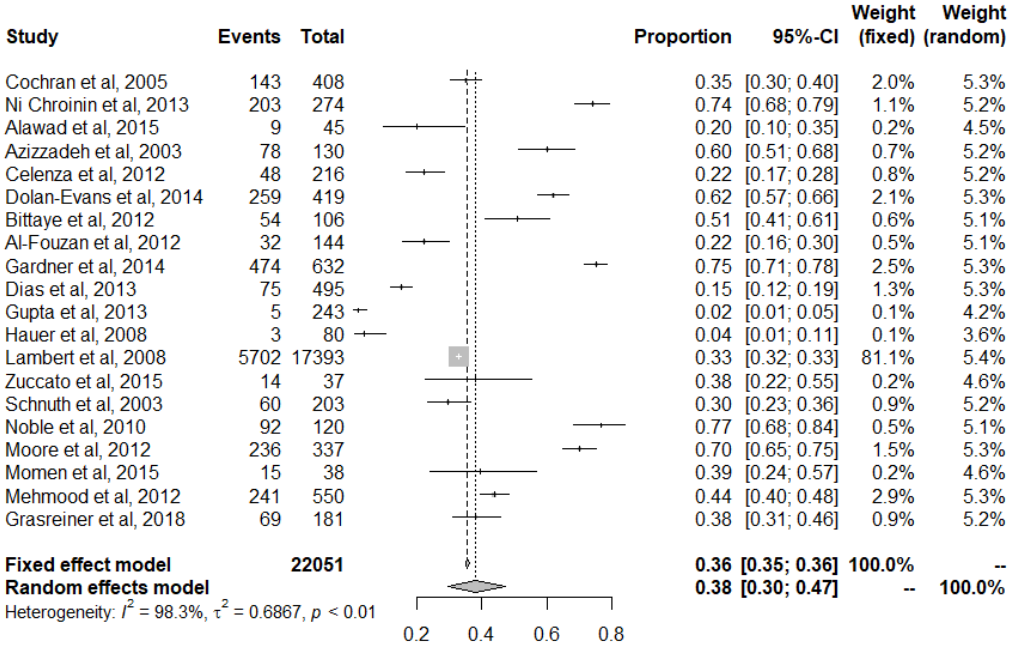


Figure S9. Forest Plot of "Income".

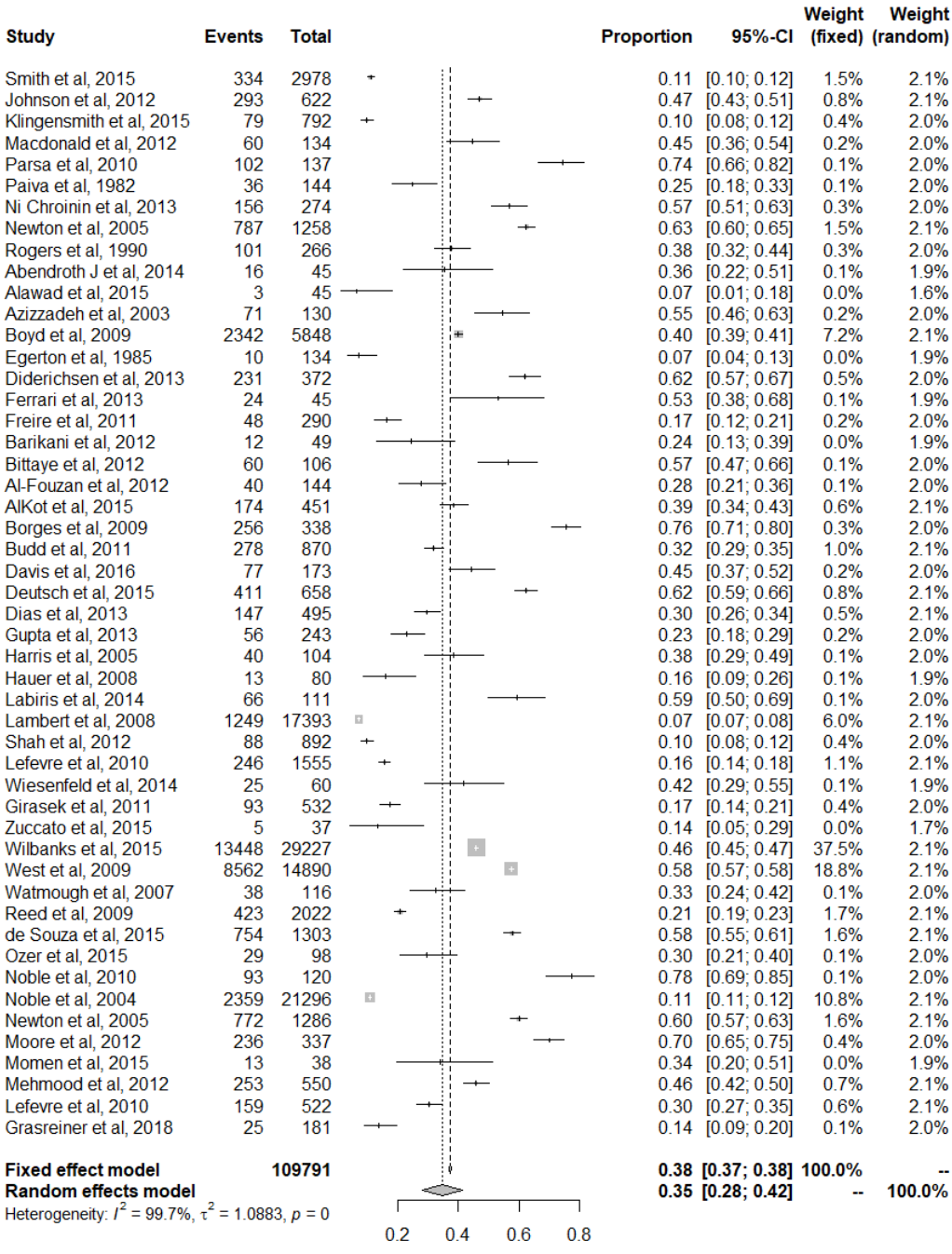


Figure S10. Forest Plot of "Length of Training".

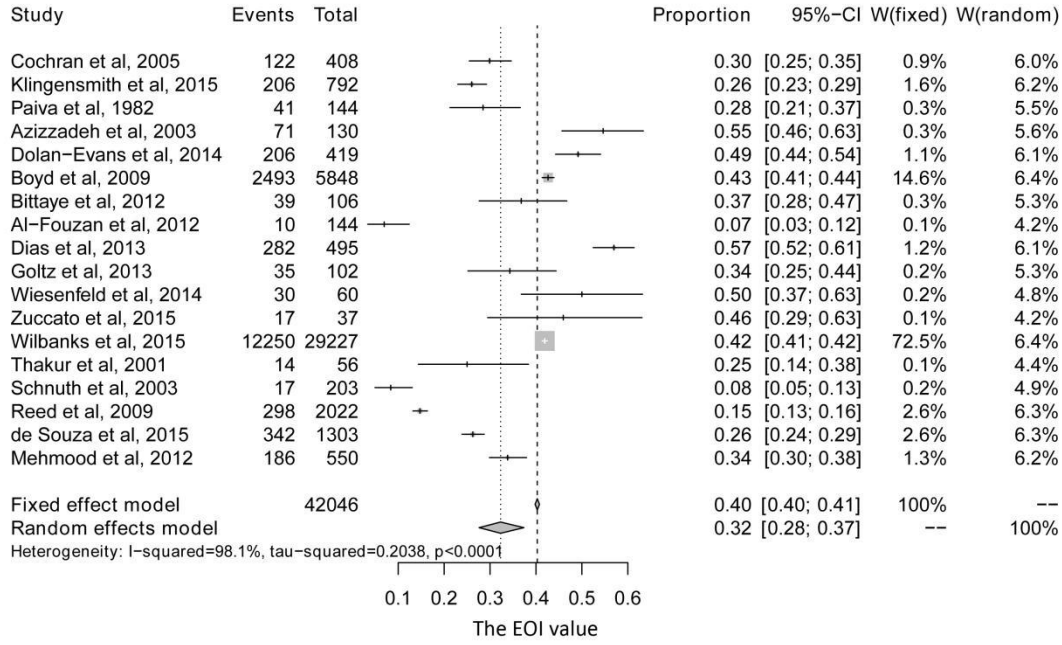


Figure S11. Forest Plot of "Prestige".

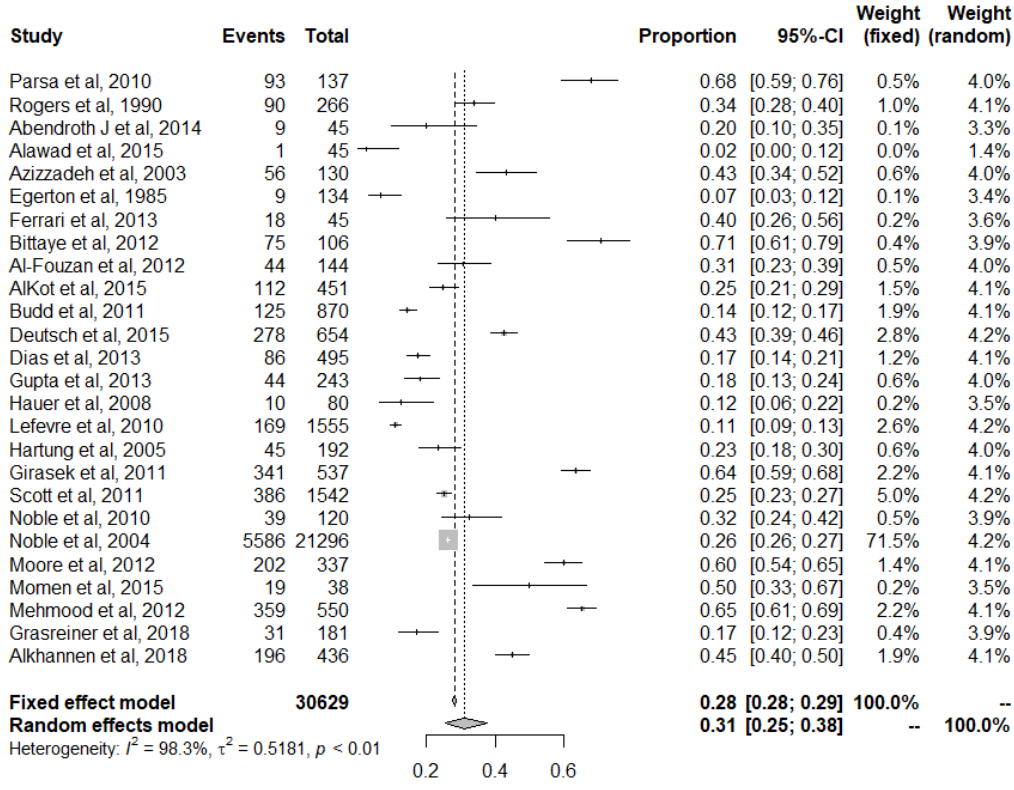


Figure S12. Forest Plot of "Advice from Others".

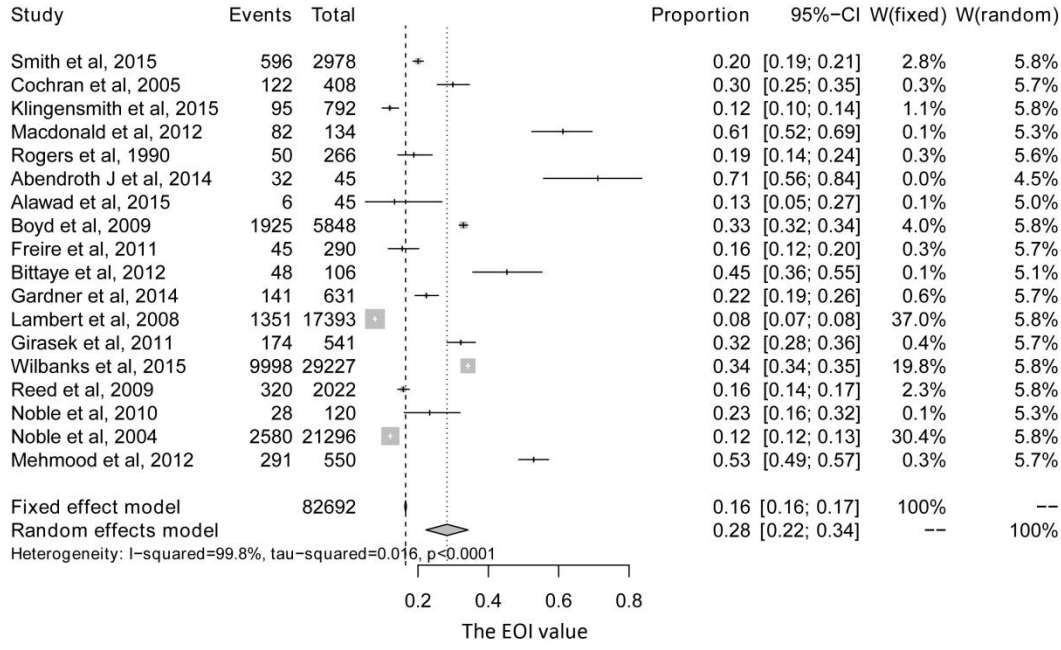


Figure S13. Forest Plot of "Student Debt".

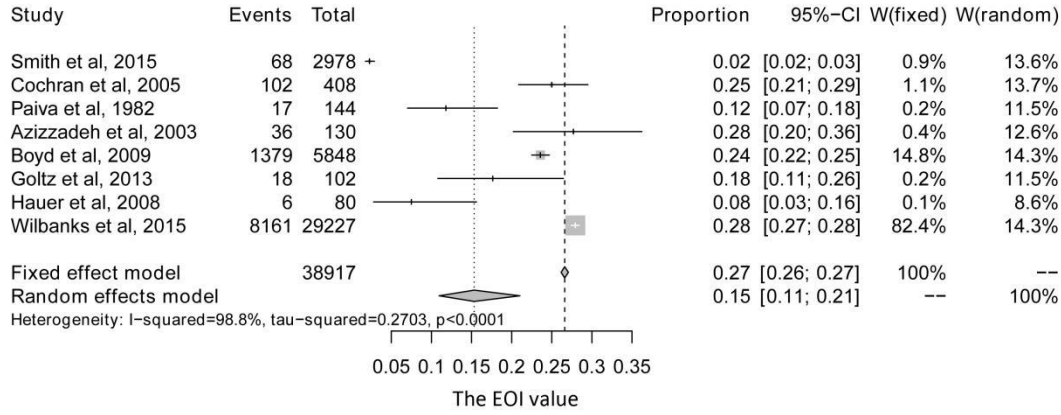
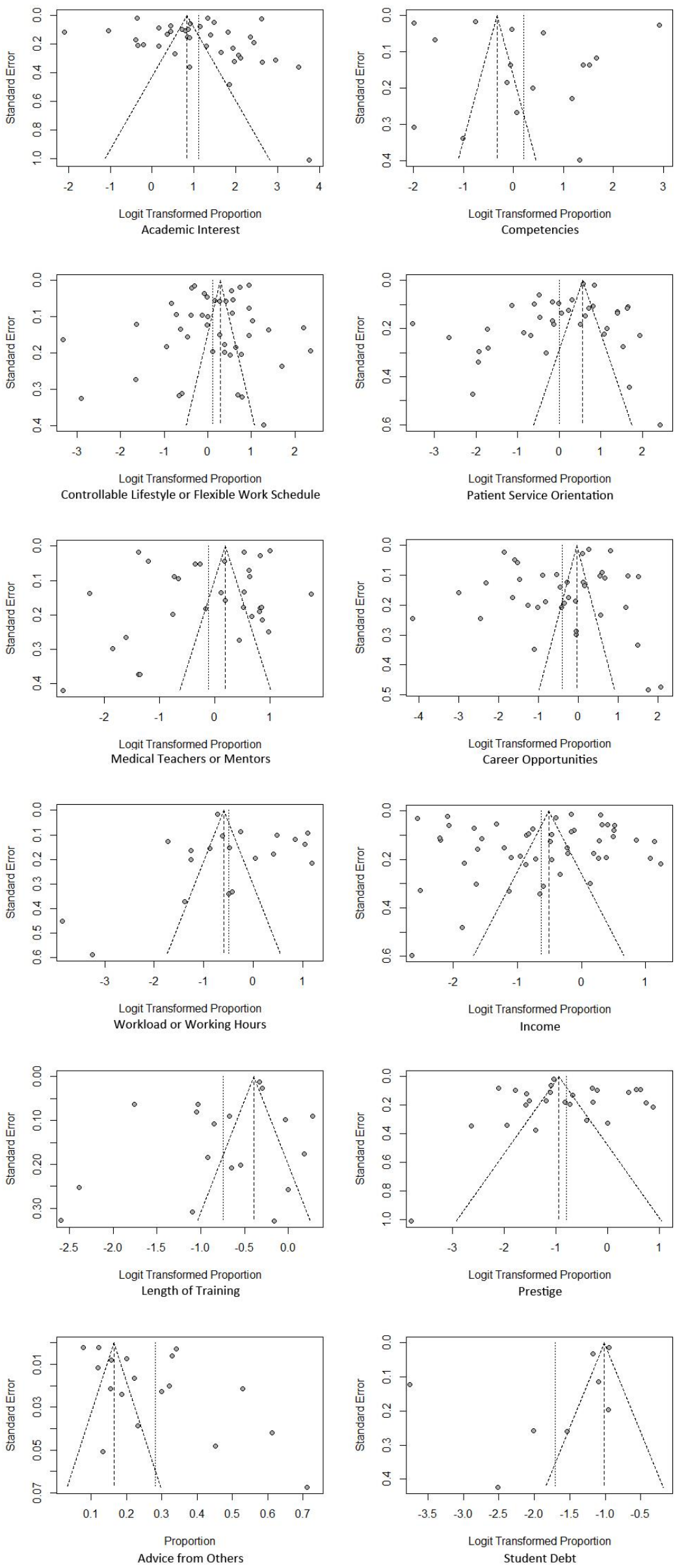


Figure S14. Funnel Plots of the Publication Bias Testing of the 12 Factors.



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5, 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7-8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

MOOSE Checklist for Meta-analyses of Observational Studies

Item No	Recommendation	Reported on Page No
Reporting of background should include		
1	Problem definition	5
2	Hypothesis statement	5
3	Description of study outcome(s)	5
4	Type of exposure or intervention used	5
5	Type of study designs used	5
6	Study population	5
Reporting of search strategy should include		
7	Qualifications of searchers (eg, librarians and investigators)	6
8	Search strategy, including time period included in the synthesis and key words	5
9	Effort to include all available studies, including contact with authors	5
10	Databases and registries searched	5
11	Search software used, name and version, including special features used (eg, explosion)	6
12	Use of hand searching (eg, reference lists of obtained articles)	5
13	List of citations located and those excluded, including justification	5-6
14	Method of addressing articles published in languages other than English	5
15	Method of handling abstracts and unpublished studies	5
16	Description of any contact with authors	5
Reporting of methods should include		
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	6
18	Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	6-7
19	Documentation of how data were classified and coded (eg, multiple raters, blinding and interrater reliability)	6-7
20	Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	6
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	6
22	Assessment of heterogeneity	6
23	Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	6-7
24	Provision of appropriate tables and graphics	5-7
Reporting of results should include		
25	Graphic summarizing individual study estimates and overall estimate	8
26	Table giving descriptive information for each study included	7
27	Results of sensitivity testing (eg, subgroup analysis)	8
28	Indication of statistical uncertainty of findings	7-9

Item No	Recommendation	Reported on Page No
Reporting of discussion should include		
29	Quantitative assessment of bias (eg, publication bias)	13
30	Justification for exclusion (eg, exclusion of non-English language citations)	13-14
31	Assessment of quality of included studies	13-14
Reporting of conclusions should include		
32	Consideration of alternative explanations for observed results	14
33	Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	14
34	Guidelines for future research	14
35	Disclosure of funding source	15

From: Stroup DF, Berlin JA, Morton SC, et al, for the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group. Meta-analysis of Observational Studies in Epidemiology. A Proposal for Reporting. *JAMA*. 2000;283(15):2008-2012. doi: 10.1001/jama.283.15.2008.

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Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Medical education and training
Keywords:	Medical students, Career choice, Meta-analysis

Title Page

Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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ABSTRACT

Objective To characterize the contributing factors that affect medical students' subspecialty choice and to estimate the extent of influence of individual factors on the students' decision-making process.

Design Systematic review and meta-analysis.

Methods A systematic search of the Cochrane Library, ERIC, Web of Science, CNKI and PubMed databases was conducted for studies published between January 1977 and June 2018. Information concerning study characteristics, influential factors, and the extent of their influence (EOI) was extracted independently by two trained investigators. EOI is the percentage level that describes how much each of the factors influenced students' choice of subspecialty. The recruited medical students includes students in medical school, internship, residency training and fellowship, who are about to or have just made a specialty choice. The estimates were pooled using a random-effects meta-analysis model due to the between-study heterogeneity.

Results Data were extracted from 75 studies (882,209 individuals). Overall, the factors influencing medical students' choice of subspecialty training mainly included academic interests (75.29%), competencies (55.15%), controllable lifestyles or flexible work schedules (53.00%), patient service orientation (50.04%), medical teachers or mentors (46.93%), career opportunities (44.00%), workload or working hours (37.99%), income (34.70%), length of training (32.30%), prestige (31.17%), advice from others (28.24%), and student debt (15.33%), with significant between-study heterogeneity (P<0.0001). Subgroup analyses revealed that the EOI of academic interests was higher in developed countries than that in developing countries (79.66%

[95% confidence interval (CI), 70.73%; 86.39%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). The EOI value of prestige was lower in developed countries than that in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01).

Conclusions This systematic review and meta-analysis provided a quantitative evaluation of the top 12 influencing factors associated with medical students' choice of subspecialty. Our findings provide the basis for the development of specific, effective strategies to optimize the distribution of physicians among different departments by modifying these influencing factors.

Systematic review registration PROSPERO CRD42017053781.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study that provide a systematic estimate of the factors associated with medical students' subspecialty choices.
- A large number of studies conducted in varied populations have been included.
- The differences in the characteristics of country, survey years, specialty, the type of data used and sample size across studies represent a major limitation of our study.

KEYWORDS Medical students, career choice, meta-analysis

Introduction

Because of the population aging, increased workload on doctors through increased number of consultations and in managing patients with multi-morbidity, the demand for physicians continues to increase; however, an imbalance in the supply of physicians in different subspecialties has become a growing concern in both developed and developing countries. [1-5] Some specialties and subspecialties, such as family medicine and palliative medicine,[6 7] are experiencing a desperate shortage of physicians, whereas other specialties and subspecialties, such as cardiology, ophthalmology and ear, nose and throat (ENT) surgery, are highly competitive specialties with low success rate for candidates.[8 9]

Specialty choice is the product of a complex interconnection of student expectation, department expectation, and competition for available spots, and student choice is where the choice begins.[10] Previous studies have suggested that medical students' choice of subspecialty is essential to the maintenance of an adequate medical workforce and a balanced development of the medical system.[11 12] However, the influencing factors underlying students' subspecialty choice have not been systemically reviewed. Recent changes in the training and practice environment may influence medical students' career choice.[13] Additionally, the variability in preferences over time and in students' attitudes towards career choices can further complicate this assessment. For example, a study in the UK indicated that half of the medical students made a definitive subspecialty choice during their first year of medical school.[14] However, students were prone to changing their subspecialty preference during medical school and internship.[15] Notably, students may also reject certain subspecialties during their medical school training, even those they have previously seriously considered.[16] Therefore, identifying the factors that influence

students' choice of subspecialty will enable a better understanding of the current shortage/overload of physicians in specific fields and contribute to policy-building and decision-making to improve the training and recruitment of students in the future. We thus conducted a systematic review and a meta-analysis to investigate the influencing factors and the extent of their influence on the choice of subspecialty training among medical students. More specifically, we focused on the following questions. First, can we gain a better understanding of students' preferences for medical specialty according to the primary influencing factor? Second, do the subgroups according to world region and survey years examined in this study differ significantly with regard to the weight that students place on the identified influencing factor?

Methods

We developed a review protocol (registration number: PROSPERO CRD42017053781) prior to commencing the study. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was used to ensure the reporting quality of this review **(Fig. S1)**.[17]

Search Strategy and Study Eligibility

We performed a literature search in June 2018 using the Cochrane Library, Medline, Web of Science, CNKI and ERIC databases without language restrictions. Articles were screened by title, abstract and reference list, and by correspondence with study investigators. Potentially relevant papers were first identified by reviewing the titles and abstracts, and the full text of each retrieved article was then assessed. A detailed example of search strategy for Medline/PubMed is shown in **Methods S1**. Studies were included if they were systematic review or cross-sectional studies, reported data on medical students, were published in peer-reviewed journals, and used a validated

method to assess the extent of a factor's influence on the choice of subspecialty, such as pediatric gastroenterology and vascular surgery, or its corresponding specialty, such as pediatrics and surgery. Because of the differences between medical education systems in the world, the medical students we recruited includes the student in medical school, internship, residency training and fellowship, containing the students who about to make a specialty choice and students who has just made a specialty choice. A guide to medical specialty, available at https://www.abms.org/member-boards/specialty-subspecialty-certificates/, were used to identify the medical specialty and subspecialty of our research. We also conducted an additional search using OpenGrey. However, no additional articles were further included. All searches were performed using Google chrome (version 54.0.2840).

Data Extraction and Quality Assessment

Each article was reviewed by two trained investigators (Y.Y. and J.L.) and the following information was independently extracted from each selected article using a standardized form: study design, geographic location, years of survey, journal, sample size, average age of the participants, the number and percentage of male participants, and the influencing factors and the extent of their influence. A third investigator was consulted if disagreements occurred. Each study may involve one or several influencing factors. An 11-item checklist which was recommended by Agency for Healthcare Research and Quality (AHRQ), used for cross-sectional studies [18], available at https://www.ncbi.nlm.nih.gov/books/NBK35156/, were used to assess the quality of the studies. All discrepancies were resolved via discussion and consensus.

Statistical Analysis

As considerable heterogeneity was expected because of the multiple sources of variances, a random effects meta-analysis model was used to estimate the influencing

factors and the extent of their influence.[19] Between-study heterogeneity was assessed using the Cochran's Q-test, and was quantified with the I^2 statistic, which was calculated to describe the percentage of total variation caused by heterogeneity across studies, with ≥50% indicating considerable heterogeneity. [20 21] Potential sources of heterogeneity were identified using meta-regression.[22] Four categorical covariates were defined as potential sources of heterogeneity by examining the studies conducted in the United States (US) vs. the studies conducted in other countries, the studies conducted before 2010 vs. those conducted after 2010, the studies concerning subspecialty only vs. those that were not specific to a subspecialty, and the studies with a sample size <200 vs. the studies with a sample size ≥200. Subgroup analyses were performed for each factor in the studies in developed countries vs. developing countries and studies conducted before 2010 vs. after 2010. The EOI value of competencies in developing countries was not statistically significant (81.21% [95% CI, 75.27%; 86.51%], P=0.1436), and no studies on the influence of student debt in developing countries were found. The Q-test based on the analysis of variance was used to compare the subgroups, with a significance threshold of 5%.[23] The influence of individual studies on the overall EOI value was explored by serially excluding each study in a sensitivity analysis. Publication bias was investigated using a funnel plot test and Egger's test.[24 25] Fill and trim approach, which imputes estimates from hypothetical negative unpublished reports,[26] was also used to investigate the publication bias if the Egger's test was significant. All analyses were performed using R (version 3.3.1, The R Foundation, Vienna, Austria). The statistical tests were 2-sided with a significance threshold of P<0.05.

Patient and public involvement: Patients and the public were not involved in development of the research question and outcome measures, nor the study design.

The study does not involve patient recruitment, and patients were not involved in conduct of the study. We plan to liaise closely with patients, special interest groups, and charities in the dissemination of our results in printed and electronic media.

Results

Study Characteristics

Seventy-five cross-sectional studies involving a total of 882,209 individuals that published between January 1977 and May 2018 were included in the present research **(Table 1).** Thirty-four studies were conducted in North America, 24 in Europe, 7 in Asia, 5 in Oceania, 3 in Africa, and 2 in South America. The median number of participants per study was 243 (range 37-29,227). Fourteen studies included students who had already selected subspecialties, whereas 61 did not. The influencing factors were ranked according to the frequency of occurrence and each factor was identified when at least 5 papers were available describing it. The influencing factors for subspecialty choice were then classified according to 17 aspects, including academic interests, controllable lifestyle or flexible work schedule (defined as flexibility that allows physicians to control the number of hours devoted to practicing the specialty), competencies, patient service orientation, medical teachers or mentors, career opportunities, workload or working hours (characterized by the physician's time spent on professional responsibilities), income, prestige, length of training, advice from others (advice from family, friends, and other students), student debt, experience with the subject, working environment, personality, gender and job security. Personality and gender are common factors that affect the choice of subspecialty among medical students, but most of the relevant literature has not reported on the extent of these factors' influence. Moreover, the funnel plots were clearly asymmetrical with regard to experience with the subject, the working

environment and job variety, indicating the existence of publication bias. Thus, the analysis of the remaining 12 influencing factors were shown in this paper. Studies assessed for influencing factors using questionnaires validated to medical students asking the extent of certain factors the studies investigated. Quality assessment scores for the included studies are listed in **Table 1**. None of the studies received a point for the second AHRQ Quality Indicator, which requires studies to list the inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications, since no comparison studies were referenced in the analyzed articles. For the remaining 10 criteria, 6 studies received 9 points, 8 studies received 8 points, 17 studies received 7 points, 33 studies received 6 points, 9 studies received 5 points and 2 studies received 4 points (scores for individual studies are presented in **Table S1**).

Primary Analysis

A meta-analysis was performed on the 12 influencing factors **(Table 2)**: academic interests **(Fig. S2)**, competencies **(Fig. S3)**, controllable lifestyle or flexible work schedule **(Fig. S4)**, patient service orientation **(Fig. S5)**, medical teachers or mentors **(Fig. S6)**, career opportunities **(Fig. S7)**, workload or working hours **(Fig. S8)**, income **(Fig. S9)**, length of training **(Fig. S10)**, prestige **(Fig. S11)**, advice from others **(Fig. S12)** and student debt **(Fig. S13)**. All the factors were significant with evidence of between-study heterogeneity ($P<0.0001$). A sensitivity analysis, in which the meta-analysis was serially repeated after the exclusion of each study, demonstrated that no individual study affected the overall extent of a factor's influence.

Meta-regression and Subgroup Analysis

We performed meta-regression to identified the potential sources of heterogeneity

using common instructions when at least 5 studies were available and at least 2 studies were in each comparator subgroup **(Table 3).** Some of the heterogeneities observed among the 12 factors can be partially explained by country, survey years, specialty and sample size.

EOI values were further analyzed by subgroup **(Table S2)** according to world region **(Fig. 1)** and survey year **(Fig. 2).** The EOI value of academic interests in developed countries was higher than that in developing countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). Conversely, a lower EOI value of prestige was found in studies conducted in developed countries than in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01). No statistically significant subgroup differences in the EOI values of the other influencing factors were noted between developed countries and developing countries**.** In addition, no statistically significant differences in the EOI values of the influencing factors were observed when subgroup analysis was performed by survey year.

Assessment of Publication Bias

We generated a funnel plot with proportion as the abscissa and standard error as the ordinate. A visual inspection of the funnel plots revealed minimal asymmetry among the various influencing factors **(Fig. S14)**, and the results were concentrated in the narrow upper part of the graph. There was evidence of small study effect in the meta-analysis of "patient service orientation" (Egger's test P=0.02). However, the trim-and-fill method showed the publication-bias corrected estimate remained statistically significant (63.79%, 95% CI, 58.20%; 69.04%).

Discussion

Implications

This systematic review and meta-analysis involved 75 studies with 882,209 medical students. Twelve influencing factors were analyzed. These factors can be classified into two categories: economic factors and non-economic factors. We found that the EOI of the economic factors, including income (34.70%) and student debt (15.33%), may not depend on the region's level of economic development. However, income remained a major influencing factor in the process of choosing a specialty or subspecialty. In the US, 15% of full-time family medicine physicians earned less than $100,000 in 2004, which is significantly less than the income earned by invasive cardiologists (median income=$427,815), neurosurgeons (median income=$211,094), and orthopedists (median income=$335,646).[27] This economic inequality made family medicine less attractive to medical school graduates.[28] Benefits such as health insurance and tuition reimbursement have been shown to be the most common economic incentives used to attract applicants.[29]

The non-economic factors can be divided into individual factors, specialty-related factors and others. First, individual factors, including academic interest and competencies, have a considerable impact on students' subspecialty choice, with EOI values of 75.29% and 55.15%, respectively. In addition, in the subgroup analysis, although academic interests were less influential in developing countries than in developed countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02), they were still the most influential of the 12 factors regardless of regional economic level. These findings indicate that subspecialties with a shortage of manpower may attract more students by increasing students' interests and improving the quality of education. Previous studies indicated that early specialty exposure in medical education may arouse students' academic interest and improve their clinical competence.[28 30] For example, an elective

extracurricular program designed to facilitate early contact with family medicine physicians was found to significantly improve students' interest and clinical skills, especially communication skills, in family medicine.[31] Furthermore, dispelling myths and espousing the positive aspects of a discipline may provide a better understanding of certain specialties; this approach could also be effective in increasing students' academic interest.[32] For instance, family medicine is often considered a discipline that requires less professional skills and knowledge. This misconception demotivates students from choosing family medicine as their future career specialty, and this trend may eventually lead to a shortage of family physicians.[32] Eliminating such prejudices may help students pay greater attention to the areas in short supply and restore their interests in other specialties.

Second, the specialty-related factors included controllable lifestyle/flexible work schedule (EOI of 53.00%), career opportunities (EOI of 44.00%), workload (EOI of 37.99%) and training length (EOI of 32.30%). Of these factors, lifestyle varied between different areas. Additionally, although certain specialties, such as general surgery, seem to have an adequate number of surgeons on a per capita basis in the US, there is still a poor geographic distribution within the surgical workforce according to the type of surgical practice.[33] The inflexible lifestyle is a common reason that students perceive surgery to be less attractive.[33] Reorganization of expected work hours within shared practices and the increased use of physician extenders and technologies such as electronic medical records may give physicians more flexibility in work schedules.[34] Moreover, providing promotion opportunities and shortening the length of training are possible strategies to recruit new staff in subspecialties that require a long period of post-graduate residency training, such as neurosurgery.[35]

Finally, other factors such as service orientation (EOI of 50.74%), medical teachers

or mentors (EOI of 46.93%), prestige (EOI of 34.68%), and advice from others (EOI of 28.24%) also contribute to the decision-making process of medical students. For example, the desire to care for patients with end-stage diseases contributed to the decision to enter palliative medicine in 86% of the medical students.[7] Additionally, exposure to mentors in a particular clinical field such as internal medicine has been strongly associated with medical students' choice of clinical field.[36] Moreover, improving the occupational prestige of areas such as family medicine, pathology, and radiology may help reshape the distribution of the workforce. [30 37 38]

In our study, several findings are especially noteworthy. First, interest was far more important than income in deciding subspecialty. In our study, interest was the top-ranked influencing factor (EOI of 75.29%) of subspecialty choice, while income was ranked lower (EOI of 34.70%). This finding argues against the possible default belief that raising physician's wages alone could solve the uneven distribution of clinicians among subspecialties. Our findings highlight that cultivating and stimulating students' professional interests may help improve the maldistribution of medical resources in a more efficient and cost-saving manner.

Second, improving abilities in a certain subspecialty of interest can greatly affect medical students' professional choice. In our study, competencies ranked second in influence, which may reflect the impact of admission conditions on students' choice of subspecialty. Hence, to reduce the risk that students are restricted to the subspecialty of their interest due to a lack of personal skills, medical education should focus more on enhancing students' personal competencies in addition to their academic interests.

Third, balancing medical resources is a complex process in practical terms, as the influencing factors are not mutually exclusive. The shortage of physicians in certain

subspecialties may increase physician workload, resulting in less time for teaching. Hence, the quality of teaching cannot be guaranteed, and students may tend to avoid choosing these subspecialties, thus worsening the imbalance in the medical workforce. Additionally, some of the 12 factors identified are not amenable to practical interventions. For example, prestige cannot be immediately increased using interventional strategies.[37] Overall, effective strategies must be multi-pronged and incorporate several different aspects, and maldistribution in the workforce should not be tackled through a simple adjustment of one influencing factor.

Interpretations of the results of this meta-analysis

Our meta-regression stratified by the study-level characteristics found that country, survey years, subspecialty and sample size may contribute to the heterogeneity between studies. There was no significant difference in the sensitivity analysis, which indicated that the results of the meta-analysis were convincing. The funnel plots and Egger's tests revealed that most of the publication bias was small (P>0.05), except for the meta-analysis of "patient service orientation". Moreover, the majority of the studies collected in the database were from developed countries rather than developing countries.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the students involved in our study included medical students at different stages of their medical education. Students' perception about different subspecialties may change during medical training until the students applies for specialty training. For example, compared to an intern, a freshman student may place greater emphasis on income and prestige when considering a career choice.[39] A subgroup analysis stratified by the stages of medical education and a secondary meta-analysis of

longitudinal studies may better reflect changes in influencing factors and the extent of their influence over time. Second, our meta-analysis summarized the data from different geographic regions around the world, and the general conclusions may not be appropriate to guide policy development in each region. Enhanced effort is needed to develop specific intervention strategies according to the specific economic level, religious beliefs, healthcare system, educational system and endemic diseases of different countries and regions. Subgroup analysis stratified by organizational and medical training factors would provide more information of the factors influencing subspecialty choice among medical students. Third, the surveys in the various studies were also conducted using different methods. Most of the questionnaires used a Likert scale. Therefore, when we converted the results to a percentage representing the extent of a factor's influence, the Likert scale items were treated as interval data.[40-42] Consequently, there may have been differences in the conversion process. Finally, the analysis relied on aggregated published data. A multicenter prospective study would provide more accurate estimate of the influencing factors and the extent of their influence on medical students' choice of subspecialty.

Conclusion

In conclusion, this systematic review and meta-analysis provided a summary evaluation of 12 influencing factors and the extent of their influence on the choice of subspecialty training among medical students. Understanding students' attitudes toward their subspecialty decision-making process could provide the basis for developing strategies to increase the attractiveness of subspecialties experiencing a shortage of manpower, thereby balancing the distribution of medical recourses.

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Legends

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Figure S5. Forest Plot of "Patient Service Orientation".

Figure S6. Forest Plot of "Medical Teachers or Mentors".

Figure S7. Forest Plot of "Career Opportunities".

Figure S8. Forest Plot of "Workload or Working Hours".

Figure S9. Forest Plot of "Income".

Figure S10. Forest Plot of "Length of Training".

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Figure S14. Funnel Plots of the Publication Bias Tests of the 12 Factors.

Table 1. Selected Characteristics of the 75 Studies Included in this Systematic Review and Meta-analysis

First Author, Year	Country	Survey years	Sample size	Average age	Men, No. (%)	Scores
Smith et al,[43] 2015	UK	2012	2,978	NR	NR	6
Cochran et al,[44] 2005	USA	2002	408	27.2	214 (52.45)	5
Hauer et al,[45] 2008	USA	2007	1,177	NR	NR	6
Johnson et al,[46] 2012	USA	2012	622	NR	NR	6
Kiolbassa et al,[47] 2011	Germany	2010	1,114	24.1	408 (36.62)	5
Klingensmith et al,[48] 2015	USA	2013	792	NR	539 (68.06)	6
Lee et al,[49] 2012	USA	2012	100	NR	58 (58)	7
Macdonald et al,[50] 2012	New Zealand	2011	134	NR	79 (58.96)	7
Parsa et al,[39] 2010	Iran	2006-2007	137	27.34	49 (35.77)	7
Paiva et al,[51] 1982	USA	1982	144	NR	NR	6
Ni Chroinin et al,[52] 2013	UK	2009-2011	274	NR	112 (40.89)	7
Newton et al,[34] 2005	USA	1998-2004	1,258	NR	642 (51.03)	8
Rogers et al,[53] 1990	USA	1989	266	NR	205 (77.07)	6
Abendroth J et al,[54] 2014	Germany	2007-2012	45	NR	14 (31)	7
Alawad et al,[55] 2015	USA	2010-2011	45	NR	36 (80)	8
Azizzadeh et al,[56] 2003	USA	2002	130	NR	NR	6
Celenza et al,[57] 2012	Australia	2009	216	NR	121 (56.02)	8
Dolan-Evans et al,[58] 2014	Australia	2013	419	NR	215 (51.31)	8
Boyd et al,[59] 2009	USA	2005-2006	5,848	NR	2,982 (50.99)	8
Egerton et al,[60] 1985	Ireland	1977-1981	134	30	82 (61.19)	6
Diderichsen et al,[61] 2013	Sweden	2006-2009	372	27	157 (42.20)	6
Ferrari et al,[62] 2013	Italy, UK	2009-2011	45	25	NR	9
Freire et al,[63] 2011	Brazil	2006-2008	290	23	102 (35.17)	7
Buddeberg-Fischer et al,[64] 2006	Switzerland	2001-2003	522	31.1	241 (46.17)	9
Dorsey et al,[65] 2005	USA	2003	11,029	NR	4,964 (45.01)	6
Ekenze et al,[66] 2013	Nigeria	2009-2010	96	25.9	NR	7
Barikani et al,[67] 2012	Australia	2008-2009	49	21.7	NR	6
Bittaye et al,[68] 2012	Gambia	2011	106	24.1	48 (45.28)	6
Bonura et al,[69] 2016	USA	2015	590	NR	321 (54.40)	9
Al-Fouzan et al,[70] 2012	Kuwait	2011-2012	144	NR	NR	7
AlKot et al,[71] 2015	Egypt	2013	451	21.8	NR	7
Borges et al,[72] 2009	USA	2001-2005	341	NR	NR	5
Budd et al,[73] 2011	UK	2011	870	22	NR	7
Corrigan et al,[74] 2007	Ireland	2007	222	NR	142 (63.96)	7
Davis et al,[75] 2016	UK	2016	173	NR	76 (43.93)	7
Deutsch et al,[76] 2015	Germany	2011	659	27.9	NR	8
Gardner et al,[77] 2014	Australia	1993-2005	631	NR	NR	7
Dias et al,[78] 2013	UK	2013	495	NR	438 (88.48)	5
Goltz et al,[79] 2013	USA	2012	102	24.5	34 (33.33)	6
Gupta et al,[80] 2013	India	2013	243	NR	179 (73.36)	6

Hanzlick et al,[81] 2008	USA	2006	161	NR	NR	6
Harris et al,[82] 2005	USA	1991-2002	104	NR	53 (50.96)	6
Hauer et al,[83] 2008	USA	2008	80	NR	NR	6
Labiris et al,[84] 2014	Greece	2014	111	23.6	55 (49.54)	6
Lambert et al,[85] 2008	UK	2007	17,393	NR	NR	6
Shah et al,[86] 2012	USA	2011	892	NR	NR	6
Lefevre et al,[87] 2010	USA	2008	1,555	NR	589 (37.88)	6
Vicente et al,[88] 2013	Chile	2013	30	NR	NR	6
Wiesenfeld et al,[89] 2014	Canada	2013	60	NR	NR	7
Lam et al,[90] 2016	Hong Kong	2015	228	23	NR	9
Hartung et al,[91] 2005	USA	2004	192	20.59	74 (38.54)	4
Girasek et al,[92] 2011	Hungary	2011	536	NR	NR	5
Zuccato et al,[93] 2015	Canada	2012	37	NR	24 (65)	6
Wilbanks et al,[94] 2015	USA	2011-2013	29,227	NR	15,164 (51.99)	9
West et al,[95] 2009	USA	2005-2007	14,890	NR	8,700 (58.43)	6
Watmough et al,[96] 2007	UK	2005	116	NR	66 (56.90)	4
Thakur et al,[97] 2001	USA	2001	56	NR	53 (95)	8
Scott et al,[98] 2011	Canada	2002-2004	1,542	NR	NR	6
Schnuth et al,[99] 2003	USA	2002	203	NR	72 (53.47)	6
Richards et al,[100] 2009	UK	2009	150	NR	108 (72.00)	5
Reed et al,[101] 2009	USA	2008	2,022	NR	1,354 (66.96)	9
de Souza et al,[102] 2015	Portugal	2012	1,303	NR	NR	7
Pikoulis et al,[103] 2010	Greece	2006-2007	87	NR	NR	6
Ozer et al,[104] 2015	Turkey	2013	98	27.7	26 (26.53)	6
Noble et al,[105] 2004	Canada	2004	21,296	NR	NR	8
Noble et al,[106] 2010	Canada	2007	120	NR	NR	5
Newton et al,[107] 2005	USA	2004	1,286	NR	NR	6
Moore et al,[108] 2012	USA	2011	337	26	179 (53.12)	6
Momen et al,[109] 2015	Iran	2014-2015	38	35.6	11 (29)	6
Mehmood et al,[110] 2012	Saudi Arabia	2012	550	NR	348 (63.27)	6
Loriot et al,[111] 2010	France	2007	44	NR	17 (39)	7
Lefevre et al,[112] 2010	France	2008	522	23.8	198 (37.93)	7
Vo et al,[113] 2017	Canada	2017	90	22.5	52 (57.78)	5
Grasreiner et al,[114] 2018	Germany	2014-2016	181	24	33 (18.10)	6
Alkhannen et al,[115] 2018	Saudi Arabia	2017	436	NA	250 (57.00)	5

Footnotes: scores: quality score of the AHRQ scale.

Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Factor	No. of studies	Total no. of participants	EOI value (%)	95 CI% of EOI value		*Cochran's Q*	*I-square* (%)	*Tau-square*	*P*-Value
				Lower	Upper				
Academic interests	38	82,366	75.29	66.93	82.11	14719.76	99.70	1.60	<0.0001
Competencies	17	76,515	55.15	33.63	74.90	23572.74	99.90	3.44	<0.0001
Controllable lifestyle or flexible work schedule	44	101,001	53.00	47.90	58.03	8624.46	99.50	0.45	<0.0001
Patient service orientation	37	46,572	50.04	44.65	55.43	2668.79	98.70	0.41	<0.0001
Medical teachers or	32	85,071	46.93	37.77	56.30	15216.32	99.80	1.14	<0.0001
Career opportunities	38	81,923	44.00	32.26	48.78	13553.20	99.70	1.15	<0.0001
Workload or working hours	20	22,051	37.99	29.59	47.19	584.81	98.30	0.69	<0.0001
Income	50	109,791	34.70	28.36	41.62	16952.48	99.70	1.09	<0.0001
Length of training	18	42,046	32.30	27.61	37.37	917.21	98.10	0.20	<0.0001
Prestige	26	30,629	31.17	26.32	37.69	1464.67	98.30	0.52	<0.0001
Advice from others	18	82,692	28.24	22.26	34.23	7679.73	99.80	0.02	<0.0001
Student debt	8	38,917	15.33	10.96	21.03	574.81	98.80	0.27	<0.0001

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Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Factor		estimate	95 CI% of estimate		*P*-Value
			Lower	Upper	
Academic interests	Country	-0.2314	-1.1575	0.6946	0.6302
	Survey years	0.3811	-0.3580	1.1202	0.2711
	Specialty	-0.4892	-1.5345	0.5562	0.4008
	Sample size	0.2362	-0.5488	1.0212	0.6537
Competencies	Country	0.6946	-1.1461	0.8938	0.8376
	Survey years	-1.0418	-2.0950	0.0114	0.0151
	Specialty	0.0904	-1.5786	1.7594	0.9398
	Sample size	-0.5720	-1.8606	0.7166	0.5823
Controllable lifestyle or flexible work schedule	Country	-0.1261	-1.1461	0.8938	0.9614
	Survey years	-0.0001	-0.4052	0.4051	0.9822
	Specialty	-0.8989	-1.4979	-0.3000	0.0035
	Sample size	-0.0518	-0.4396	0.3361	0.7203
Patient service orientation	Country	-0.6238	-1.3118	0.0642	0.0833
	Survey years	-0.0414	-0.6912	0.6083	0.8524
	Specialty	-1.5982	-2.5227	-0.6737	0.0010
	Sample size	-0.1157	-0.7473	0.5159	0.6358
Medical teachers or mentors	Country	0.7395	0.3117	1.1674	0.0007
	Survey years	0.1133	-0.3580	0.5845	0.6376
	Specialty	0.0605	-0.4441	0.5652	0.8141
	Sample size	-0.1202	-0.5567	0.3163	0.5894
Career opportunities	Country	0.1075	-0.7030	0.9179	0.5828
	Survey years	0.3284	-0.3913	1.0480	0.7546
	Specialty	-0.9292	-1.8015	-0.0570	0.0077
	Sample size	0.3654	0.1156	1.5478	0.0081
Workload or working hours	Country	-0.4535	-1.5086	0.6016	0.3981
	Survey years	0.4624	-0.5417	1.4665	0.3922
	Specialty	-0.9878	-2.1727	0.1972	0.1070
	Sample size	0.0982	-0.8589	1.0553	0.8205
Income	Country	0.1058	-0.4665	0.6781	0.7390
	Survey years	0.0999	-0.4379	0.6377	0.8774
	Specialty	-0.6457	-1.3267	0.0352	0.0480
	Sample size	0.0523	-0.4826	0.5872	0.6786
Length of training	Country	-0.1559	-1.2782	0.9664	0.7854
	Survey years	-0.2158	-1.4089	0.9772	0.7229
	Specialty	0.3959	-0.9585	1.7502	0.5667
	Sample size	0.1565	-0.6631	0.9761	0.7082
Prestige	Country	-0.3346	-1.0799	0.4106	0.3485
	Survey years	-0.4513	-1.1378	0.2352	0.0950
	Specialty	-1.0112	-1.8980	-0.1244	0.0172
	Sample size	0.0355	-0.6013	0.6723	0.5214
Advice from others	Country	-0.0097	-0.0722	0.0529	0.9328
	Survey years	-0.0861	-0.1471	-0.0251	0.0057

	Specialty	-0.2017	-0.2790	-0.1244	<0.0001
	Sample size	0.2125	0.1309	0.2941	<0.0001
	Country	2.7853	2.0544	3.5162	0.0001
Student debt	Survey years	-0.1567	-0.6707	0.3573	0.5502
	Sample size	-0.5248	-1.0108	-0.0388	0.0343

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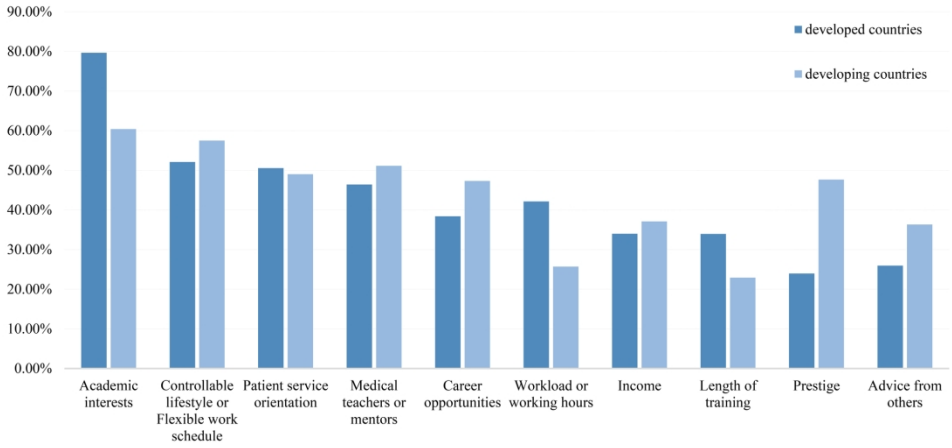


Figure 1. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region.

190x107mm (300 x 300 DPI)

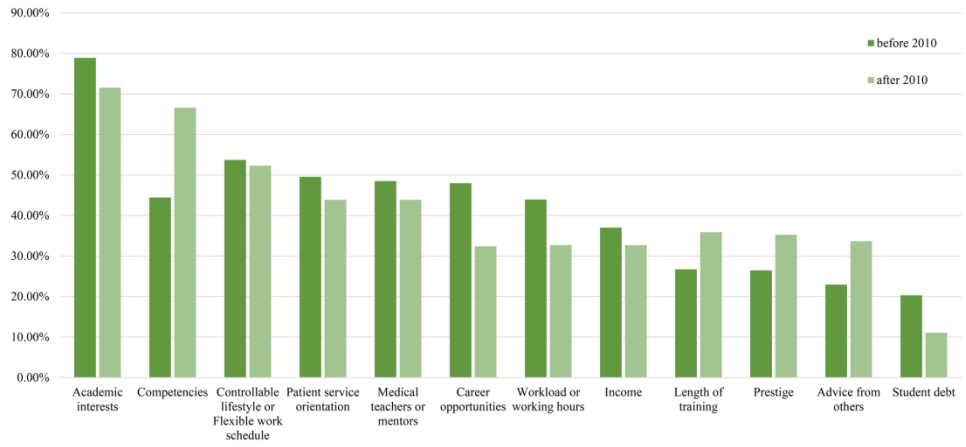


Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

190x107mm (300 x 300 DPI)

SI Methods. Search strategy used in the current systematic review and meta-analysis.

Medical Students

1. Students, Medical [Mesh]
2. Medical students
3. Medical student
4. Student, Medical
5. OR / 1 – 4

Subspecialty Choice

6. Career choices
7. Choice, Career
8. Choices career
9. Specialties
10. Sub-specialties
11. Sub-discipline
12. OR / 6 – 11

Study design

13. Cross sectional study
14. Cross sectional study [Publication Type]
15. Cross sectional study [Mesh Terms]
16. Systematic review
17. Systematic review [Publication Type]
18. Systematic review [Mesh Terms]
19. Meta-analysis [Title/Abstract]
20. Meta-analysis [Mesh Terms]
21. Meta-analysis [Publication Type]
22. OR / 12 – 21

Factors

23. Factors

Combined search

23. #5 AND #12AND #22 AND #2

Abbreviations: MeSH, Medical Subject Heading in PubMed

Table S1. Quality assessment of the included studies

	Quality assessment criteria	1	2	3	4	5	6	7	8	9	10	11	Scores
1	Smith et al,[41] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
2	Cochran et al,[42] 2005	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
3	Hauer et al,[43] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
4	Johnson et al,[44] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
5	Kiolbassa et al,[45] 2011	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
6	Klingensmith et al,[46] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
7	Lee et al,[47] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
8	Macdonald et al,[48] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
9	Parsa et al,[37] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
10	Paiva et al,[49] 1982	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
11	Ni Chroinin et al,[50] 2013	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
12	Newton et al,[32] 2005	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
13	Rogers et al,[51] 1990	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
14	Abendroth J et al,[52] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	Y	7
15	Alawad et al,[53] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	N	8
16	Azizzadeh et al,[54] 2003	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
17	Celenza et al,[55] 2012	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
18	Dolan-Evans et al,[56] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	Y	8
19	Boyd et al,[57] 2009	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
20	Egerton et al,[58] 1985	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
21	Diderichsen et al,[59] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
22	Ferrari et al,[60] 2013	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
23	Freire et al,[61] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
24	Buddeberg-Fischer et al,[62] 2006	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
25	Dorsey et al,[63] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
26	Ekenze et al,[64] 2013	Y	U	Y	Y	Y	Y	Y	N	N	Y	N	7
27	Barikani et al,[65] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
28	Bittaye et al,[66] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
39	Bonura et al,[67] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
30	Al-Fouzan et al,[68] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
31	AlKot et al,[69] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
32	Borges et al,[70] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
33	Budd et al,[71] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
34	Corrigan et al,[72] 2007	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
35	Davis et al,[73] 2016	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
36	Deutsch et al,[74] 2015	Y	U	Y	Y	Y	Y	N	Y	Y	Y	N	8
37	Gardner et al,[75] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	7
38	Dias et al,[76] 2013	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
39	Goltz et al,[77] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
40	Gupta et al,[78] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
41	Hanzlick et al,[79] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
42	Harris et al,[80] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
43	Hauer et al,[81] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
44	Labiris et al,[82] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
45	Lambert et al,[83] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
46	Shah et al,[84] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
47	Lefevre et al,[85] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
48	Vicente et al,[86] 2013	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
49	Wiesenfeld et al,[87] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
50	Lam et al,[88] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
51	Hartung et al,[89] 2005	Y	U	Y	Y	N	Y	N	N	N	N	N	4
52	Girasek et al,[90] 2011	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
53	Zuccato et al,[91] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
54	Wilbanks et al,[92] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
55	West et al,[93] 2009	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
56	Watmough et al,[94] 2007	Y	U	Y	Y	N	N	N	N	N	Y	N	4
57	Thakur et al,[95] 2001	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
58	Scott et al,[96] 2011	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
59	Schnuth et al,[97] 2003	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
60	Richards et al,[98] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
61	Reed et al,[99] 2009	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
62	de Souza et al,[100] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
63	Pikoulis et al,[101] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
64	Ozer et al,[102] 2015	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
65	Noble et al,[103] 2004	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
66	Noble et al,[104] 2010	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
67	Newton et al,[105] 2005	Y	U	Y	Y	N	Y	Y	N	N	Y	N	6
68	Moore et al,[106] 2012	Y	U	Y	Y	Y	Y	N	Y	N	N	N	6
69	Momen et al,[107] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
70	Mehmood et al,[108] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
71	Loriot et al,[109] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
72	Lefevre et al,[110] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
73	Vo et al,[111] 2017	Y	U	Y	Y	Y	N	N	N	N	Y	N	5
74	Grasreiner et al,[112] 2018	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
75	Alkhannen et al,[113] 2018	Y	U	Y	Y	N	N	Y	N	N	Y	N	5

Quality assessment criteria in detail

1. Define the source of information (survey, record review).

2. List the inclusion and exclusion criteria for the exposed and unexposed subjects (cases and controls) or refer to previous publications.

3. Indicate the time period used for identifying patients.

4. Indicate whether the subjects were consecutive if not population-based.

5. Indicate whether the evaluators of the subjective components of the study were masked to the other aspects of participants' status.

6. Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)

7. Explain any patient exclusion from the analyses.

8. Describe how confounding was assessed and/or controlled.

9. If applicable, explain how missing data were handled in the analysis.

10. Summarize the patient response rates and the completeness of the data collection.

11. Clarify what follow-up, if any, was expected and the percentage of patients with incomplete data or follow-up.

"Y": Yes; "N": No; "U": Unclear.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Factor		No. of studies	Total no. of participants	Extent of influence (%)	95 CI% of EOI value		*I-square* (%)	*P*-Value	*Q*-Value
					Lower	Upper			
Academic interest	developed	28	80,000	79.66	70.73	86.39	99.8	0.02	3.51
	developing	10	2,366	60.41	43.44	75.19	98.0		
	before 2010	29	44,174	78.88	69.04	86.22	99.7	0.40	1.21
	after 2010	9	38,192	71.54	57.66	82.27	99.6		
Competencies	before 2010	9	43,134	44.40	29.11	60.83	99.8	0.21	1.86
	after 2010	8	33,381	66.60	34.48	88.31	99.8		
Controllable lifestyle or flexible work schedule	developed	37	100,980	52.11	46.52	57.65	99.6	0.63	0.68
	developing	7	2,017	57.50	45.81	68.41	95.9		
	before 2010	22	62,945	53.72	47.48	59.84	99.4	0.97	0.05
	after 2010	22	40,056	52.29	43.51	60.93	99.2		
Patient service orientation	developed	27	44,235	50.56	44.68	56.42	98.8	0.74	0.48
	developing	10	2,337	49.02	31.62	66.67	98.1		
	before 2010	18	40,997	49.56	43.29	55.84	98.8	0.70	0.54
	after 2010	19	5,579	43.87	38.62	63.80	98.3		
Medical teachers or mentors	developed	28	84,076	46.43	36.63	56.52	99.8	0.73	0.48
	developing	4	995	51.14	33.97	68.04	95.4		
	before 2010	21	49,654	48.48	36.93	60.19	99.8	0.70	0.54
	after 2010	11	35,417	43.87	27.94	61.18	99.7		
Career opportunities	developed	31	79,867	38.41	29.61	48.04	99.8	0.60	0.74
	developing	7	2,056	47.32	30.38	64.91	98.1		
	before 2010	20	43,417	47.97	33.54	62.74	99.8	0.24	1.68
	after 2010	18	38,506	32.38	21.68	45.31	99.5		
Workload or working hours	developed	15	20,970	42.14	31.35	53.72	98.6	0.34	1.39
	developing	5	1,081	25.72	13.29	43.88	95.3		
	before 2010	9	19,456	43.93	29.43	59.54	98.8	0.41	1.21
	after 2010	11	2,595	32.70	29.43	59.54	97.4		
Income	developed	39	107,091	34.01	26.89	41.93	99.8	0.84	0.29
	developing	11	2,700	37.11	27.06	48.41	96.4		
	before 2010	25	68,714	37.01	25.95	49.62	99.8	0.41	1.18
	after 2010	25	41,077	32.67	26.04	40.07	98.9		
Length of training	developed	15	41,246	33.95	28.72	39.60	98.4	0.31	1.48
	developing	3	800	22.92	10.94	41.85	94.0		
	before 2010	7	8,811	26.72	15.89	41.29	98.9	0.28	1.59
	after 2010	11	33,234	35.87	29.67	42.59	96.9		
Prestige	developed	17	27,987	23.96	19.20	29.47	97.3	0.01	4.71
	developing	9	2,642	47.65	34.41	61.24	97.6		
	before 2010	12	25,542	26.46	20.78	33.03	96.7	0.25	1.67
	after 2010	14	5,087	35.22	24.70	47.40	98.3		
Advice from others	developed	14	81,205	25.95	19.27	32.64	99.8	0.36	1.33
	developing	4	1,487	36.34	18.91	53.77	98.1		
	before 2010	10	48,319	22.93	17.85	28.01	99.5	0.31	1.47
	after 2010	8	34,373	33.65	25.12	42.18	99.1		
Student debt	before 2010	5	6,610	20.29	15.86	25.57	81.8	0.69	0.59
	after 2010	3	32,307	11.08	1.58	49.08	99.6		

Figure S1. Flow Diagram of the Study Inclusion.

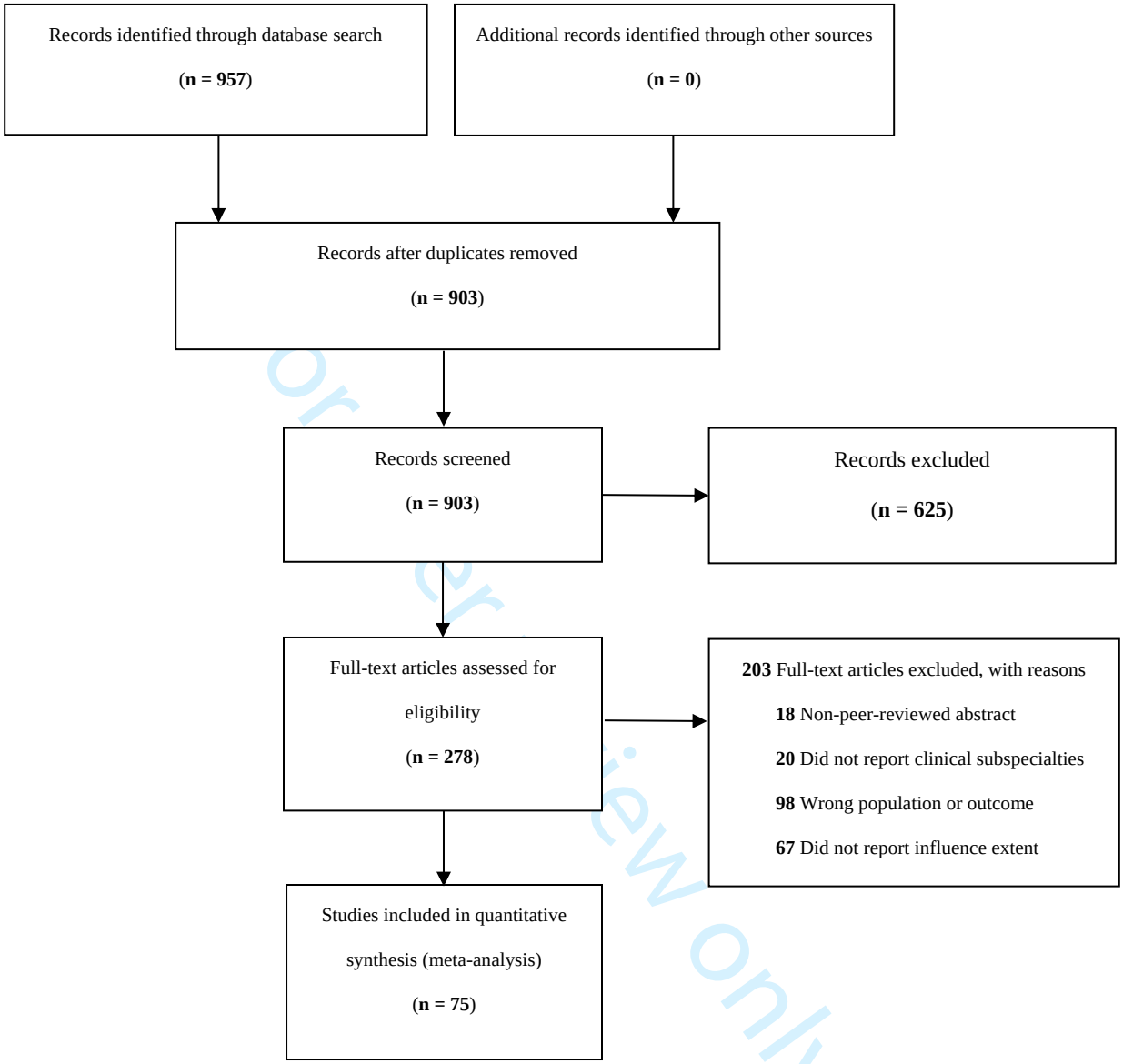


Figure S2. Forest Plot of "Academic Interest".

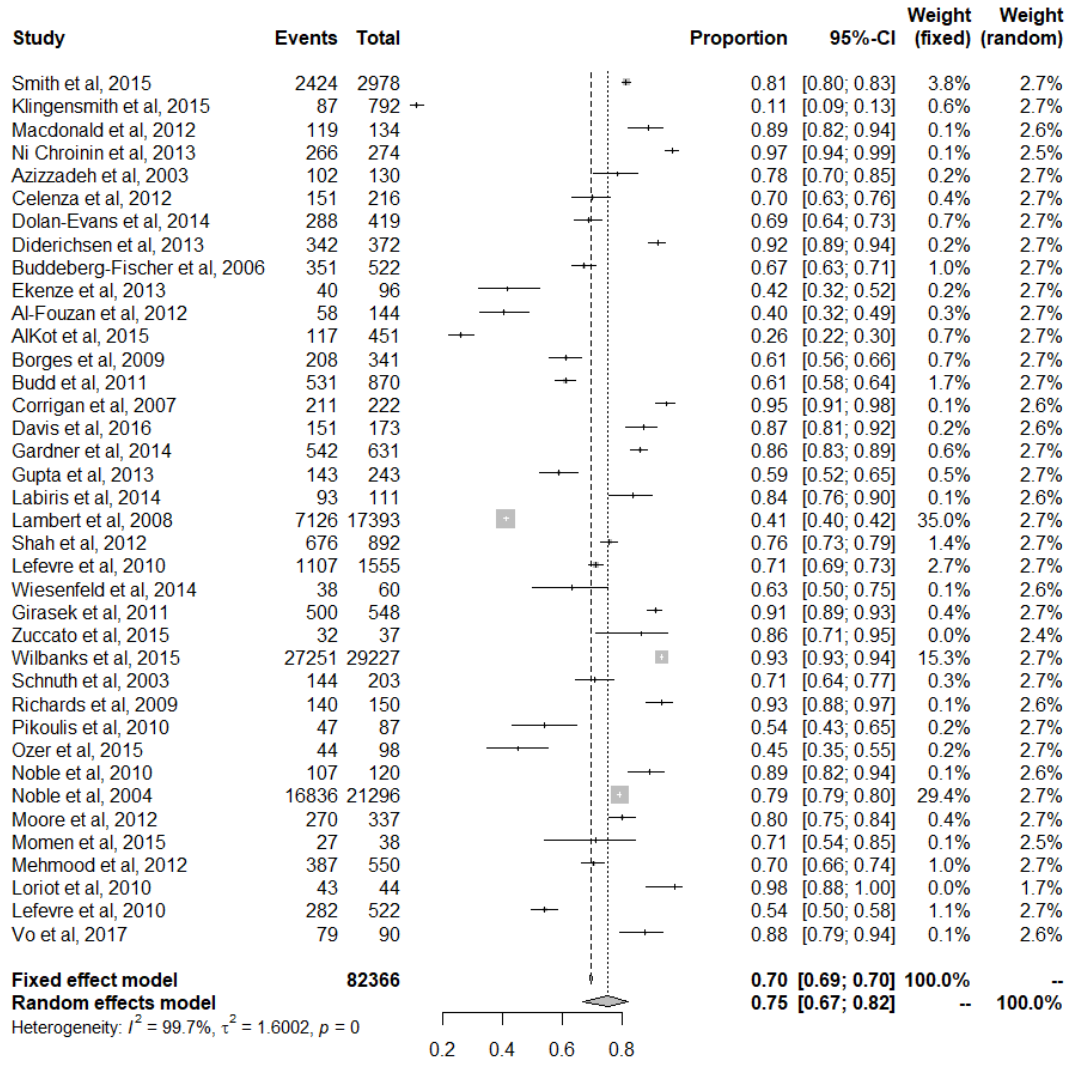


Figure S3. Forest Plot of "Competencies".

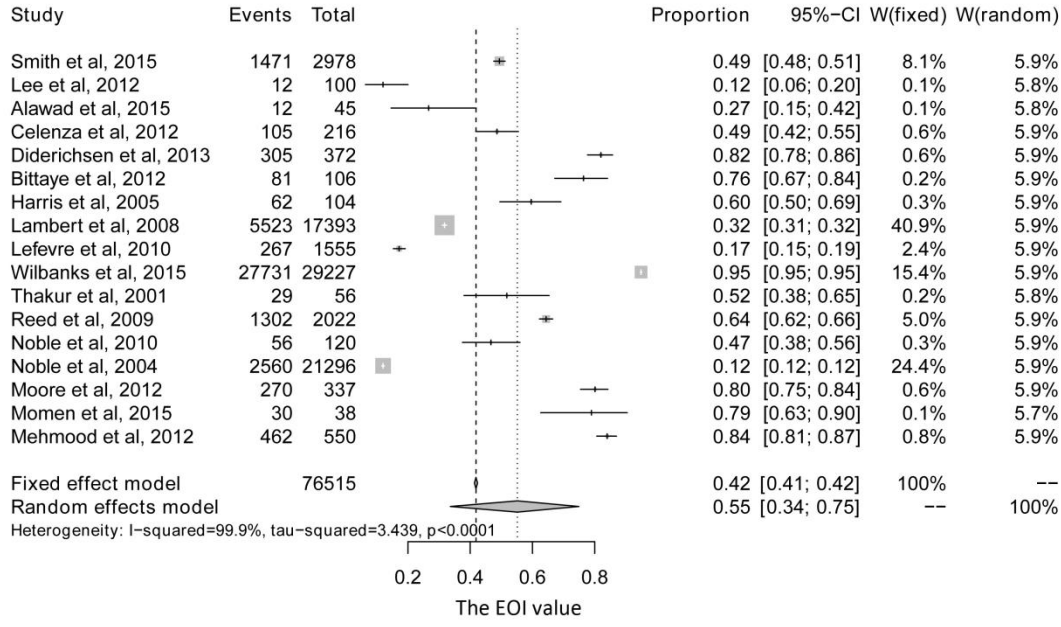


Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

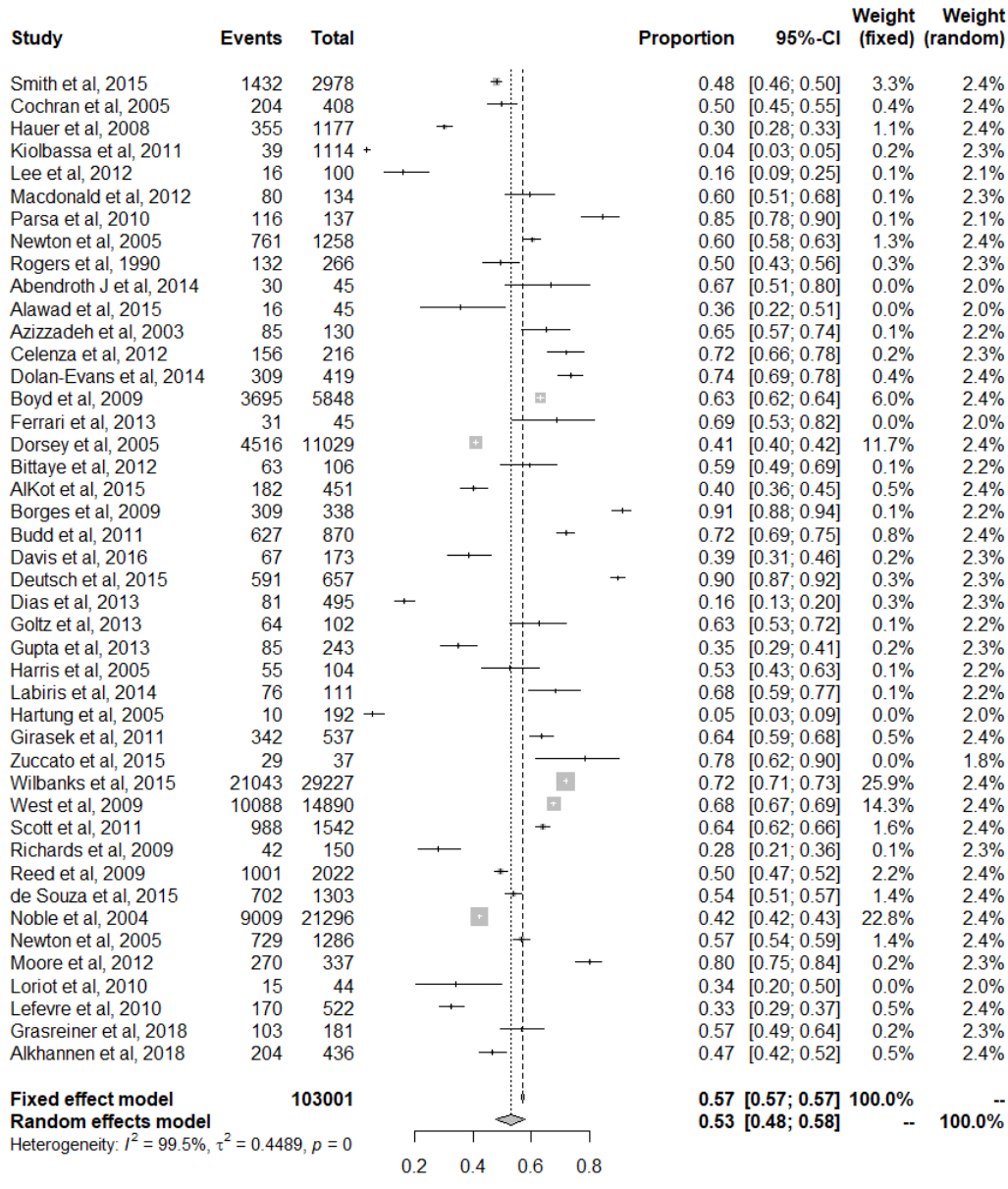


Figure S5. Forest Plot of "Patient Service Orientation".

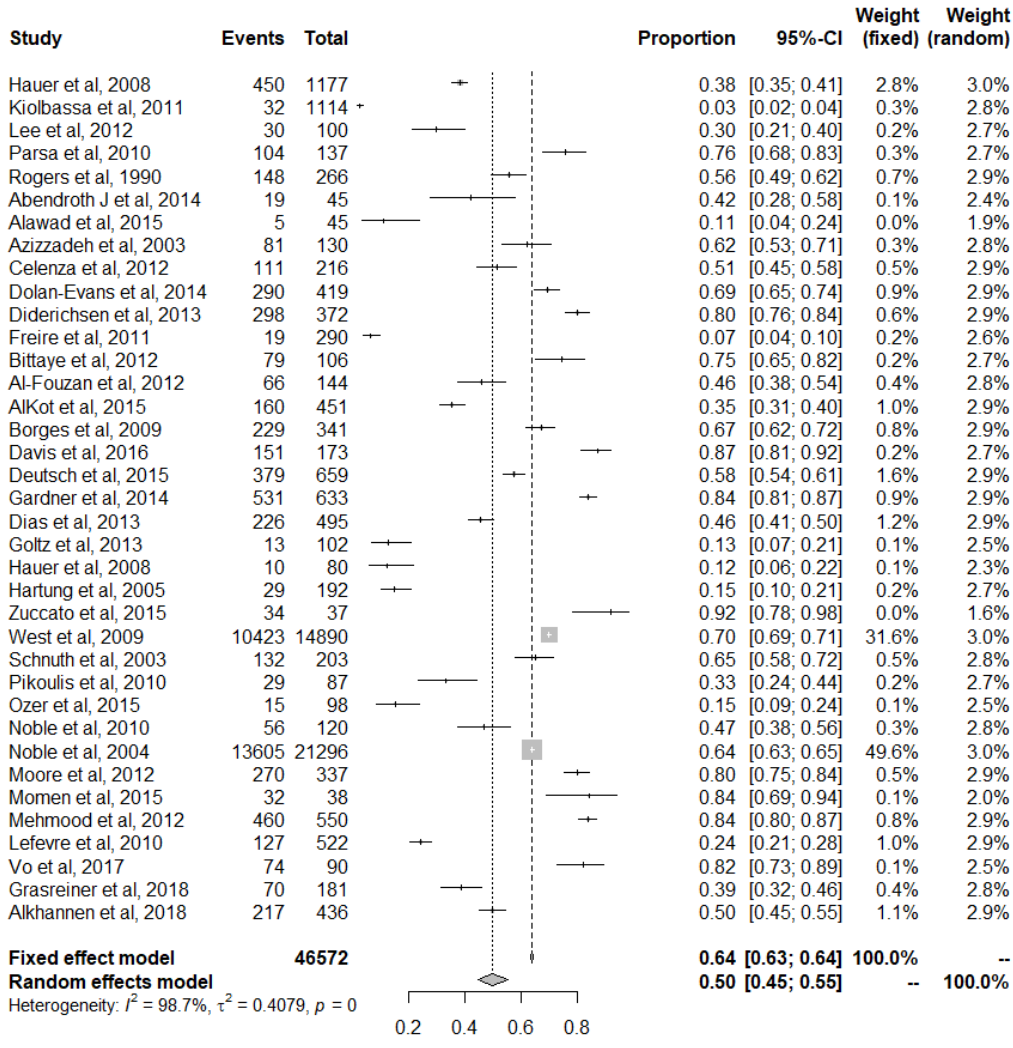


Figure S6. Forest Plot of "Medical Teachers or Mentors".

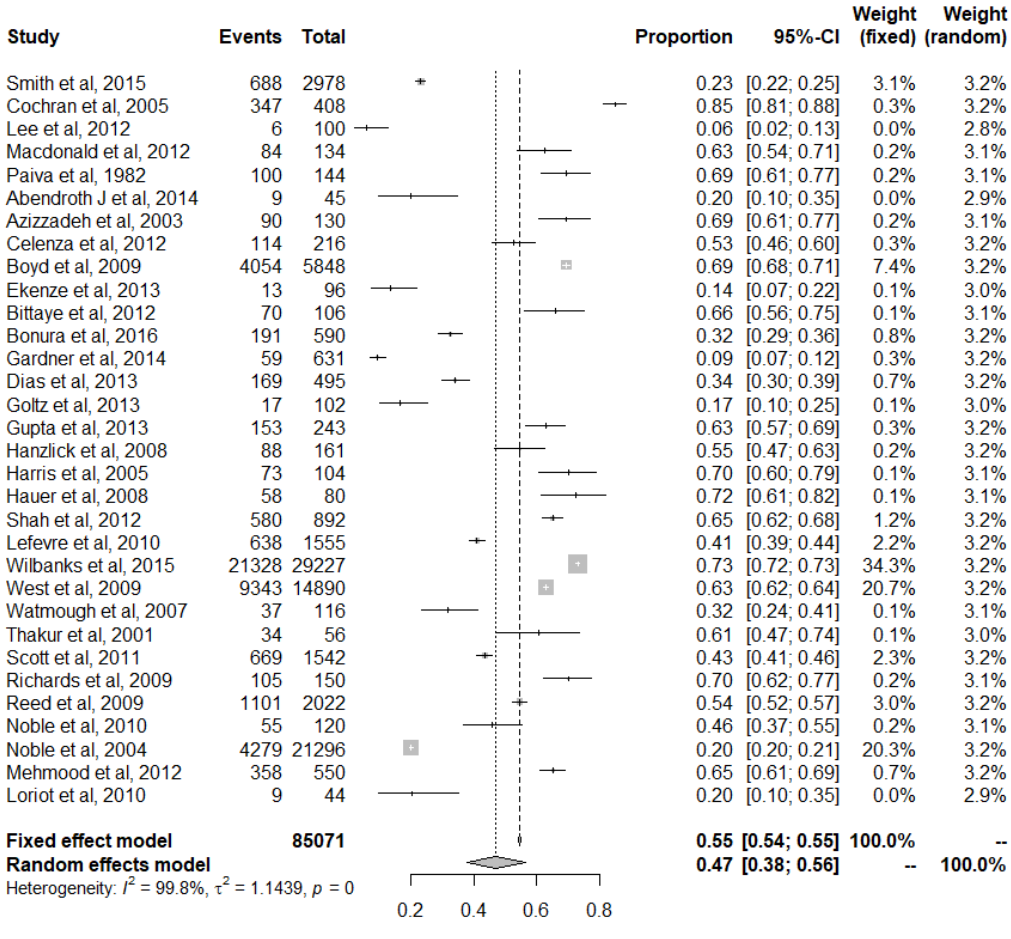


Figure S7. Forest Plot of "Career Opportunities".

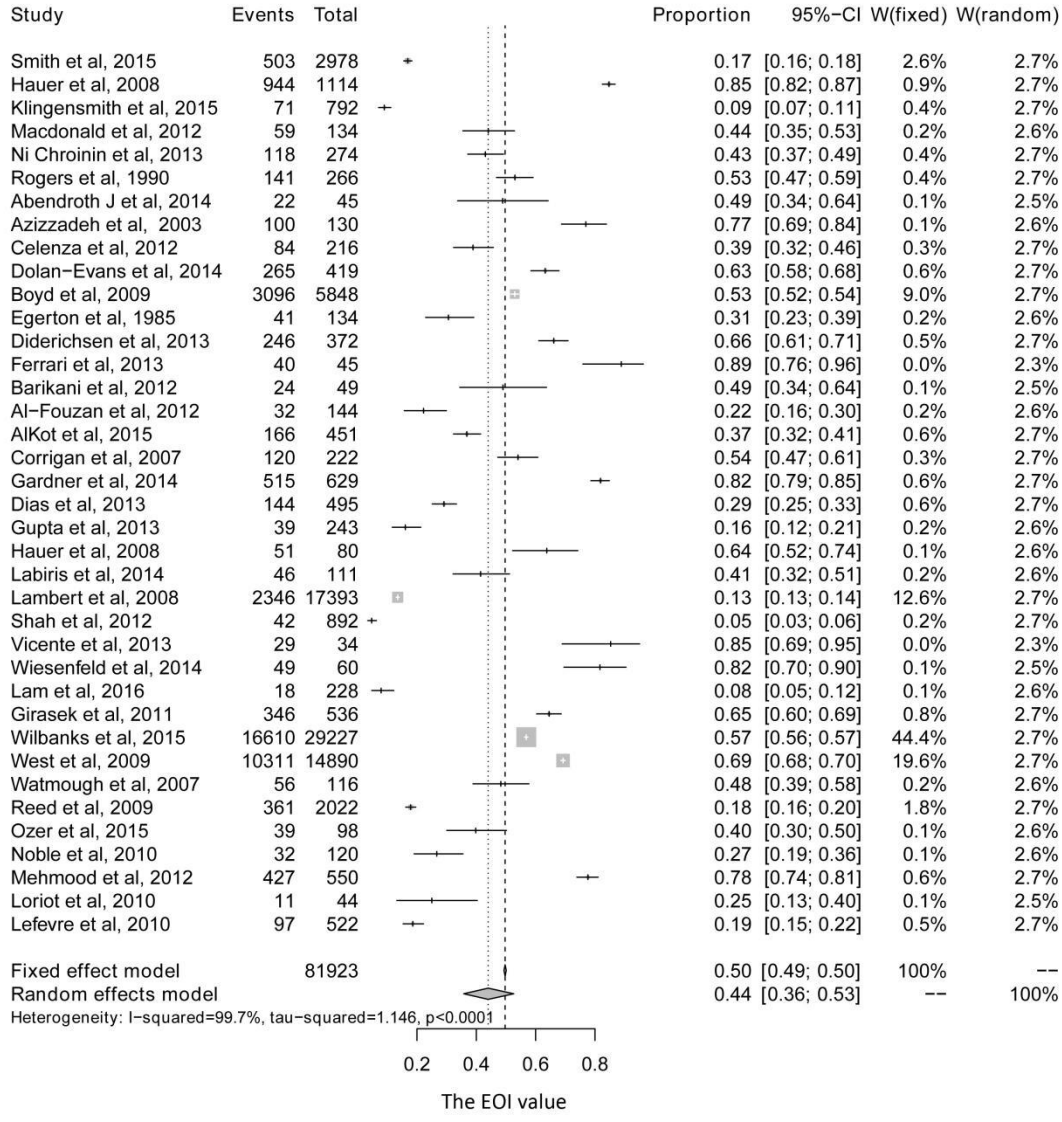


Figure S8. Forest Plot of "Workload or Working Hours".

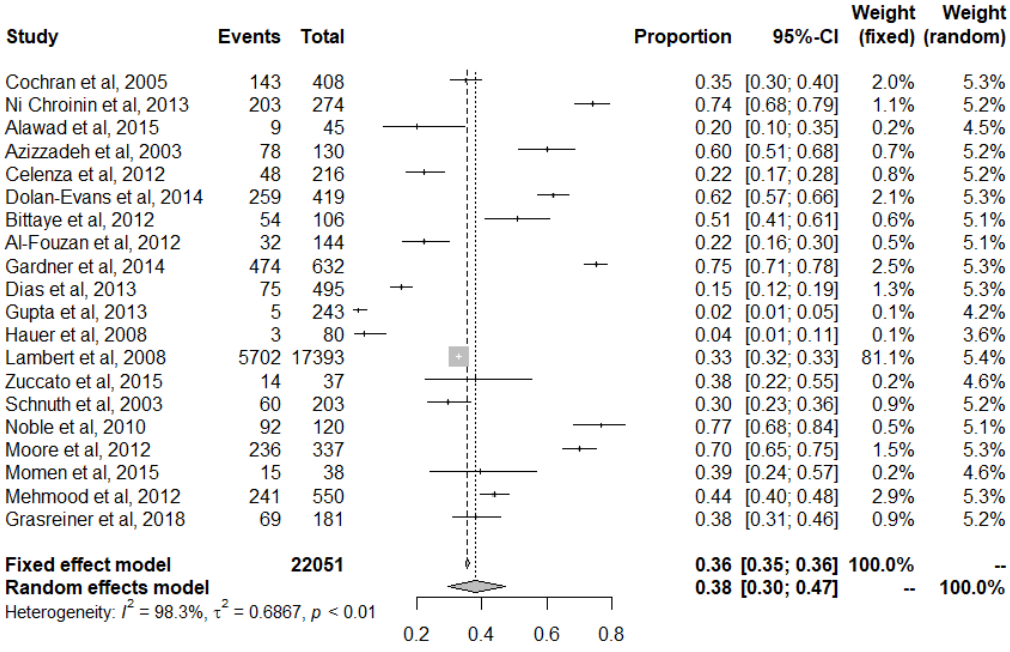


Figure S9. Forest Plot of "Income".

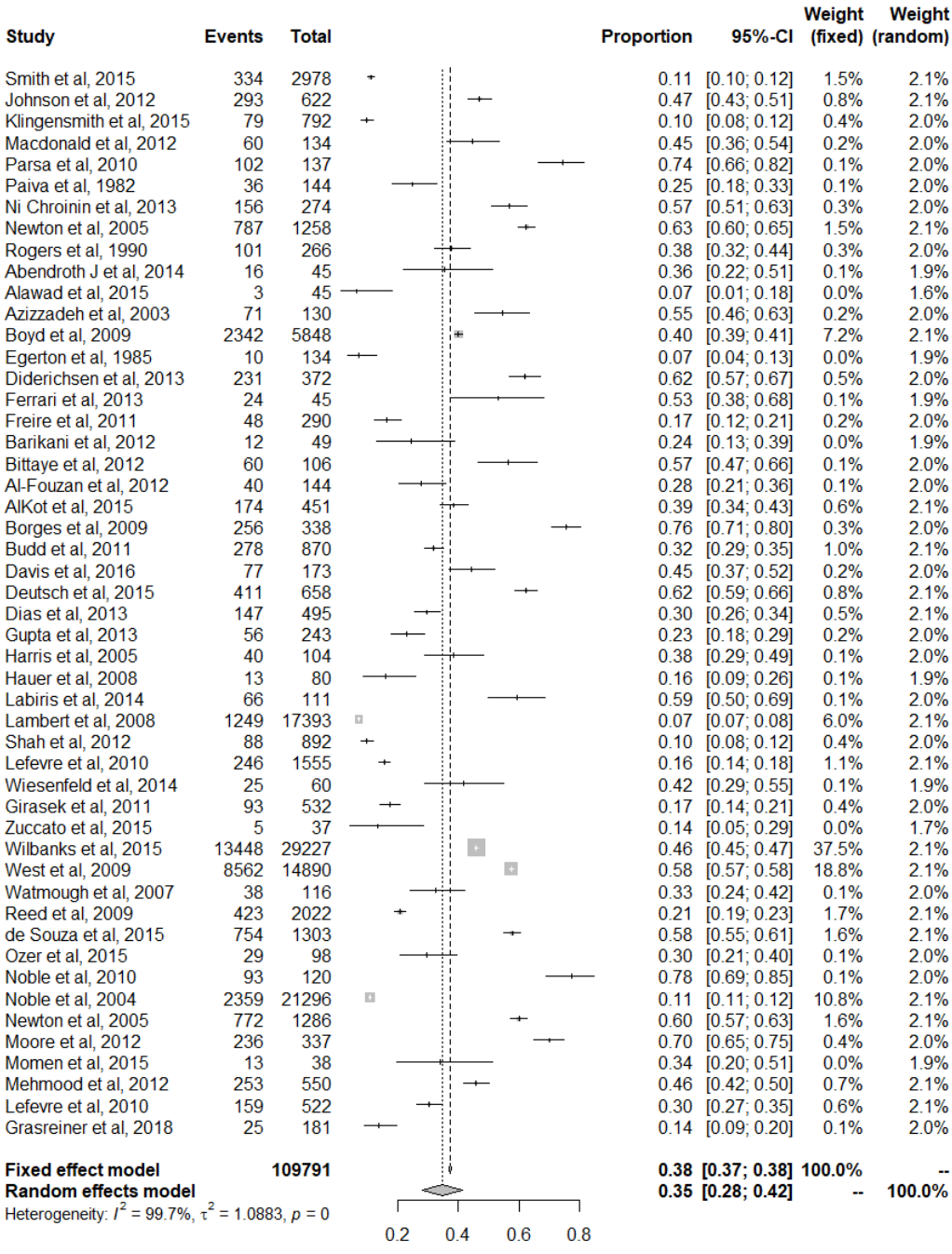


Figure S10. Forest Plot of "Length of Training".

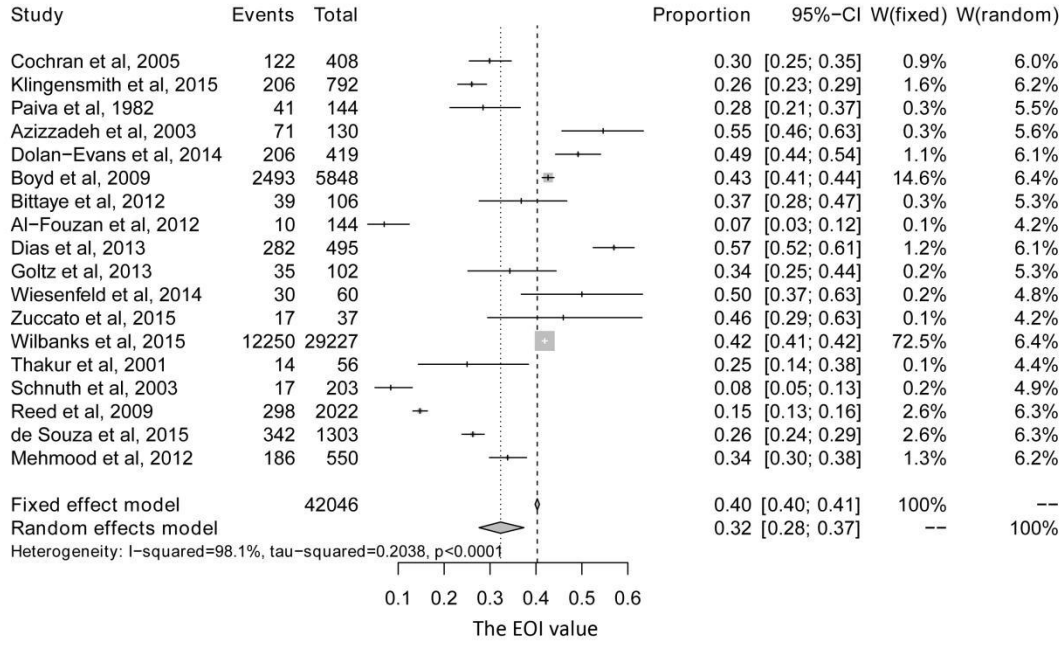


Figure S11. Forest Plot of "Prestige".

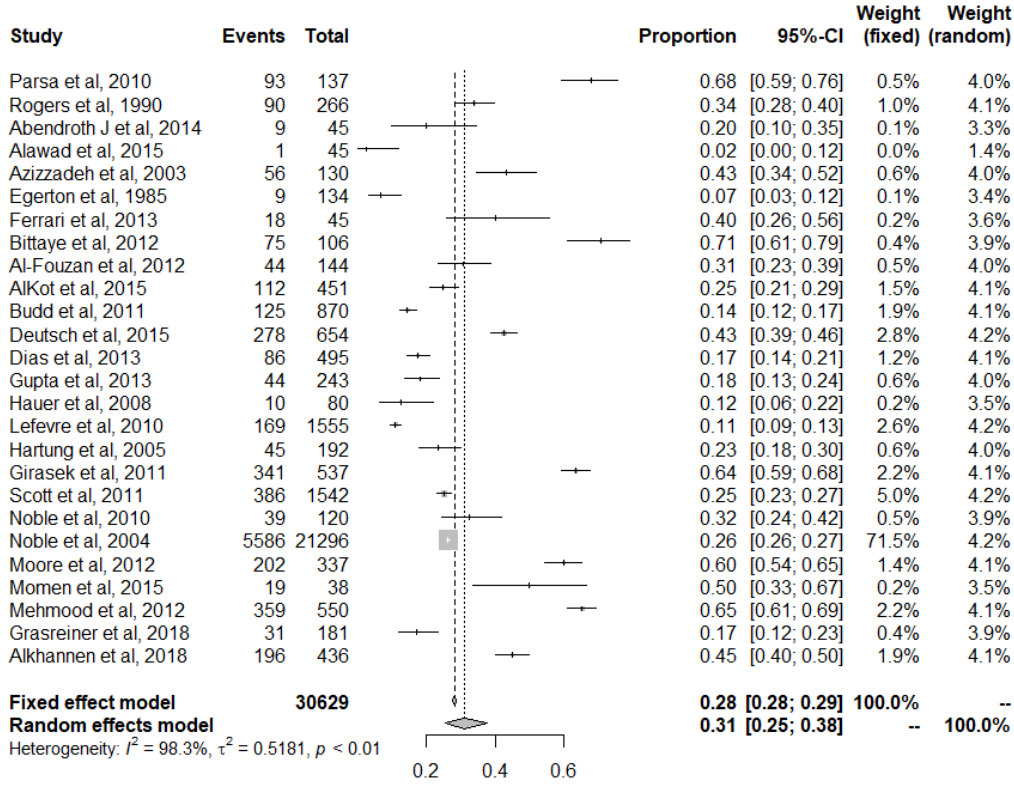


Figure S12. Forest Plot of "Advice from Others".

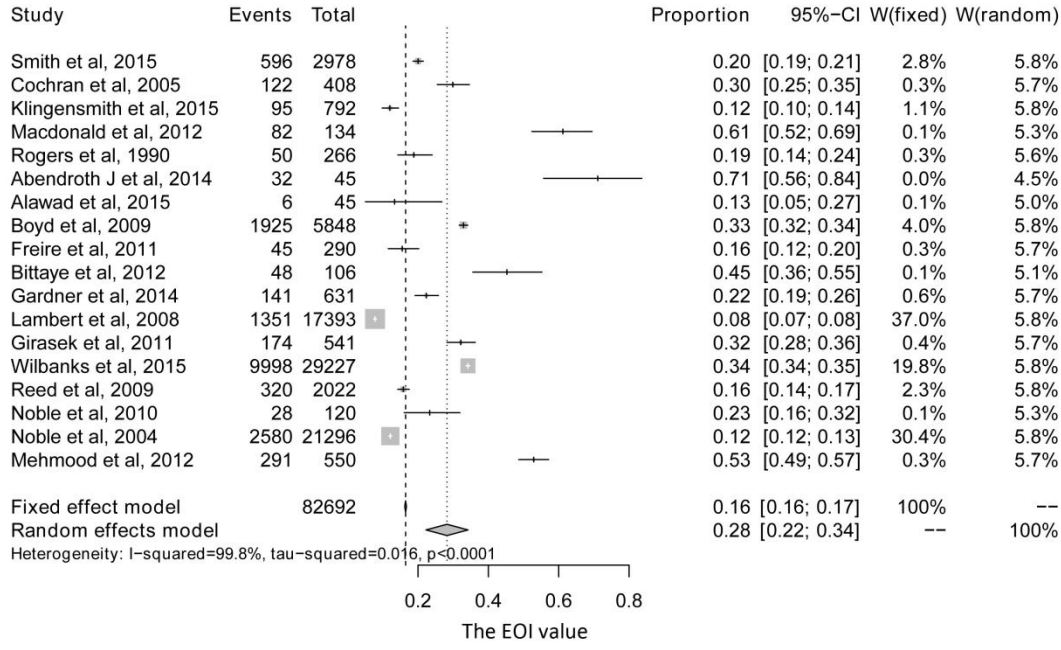


Figure S13. Forest Plot of "Student Debt".

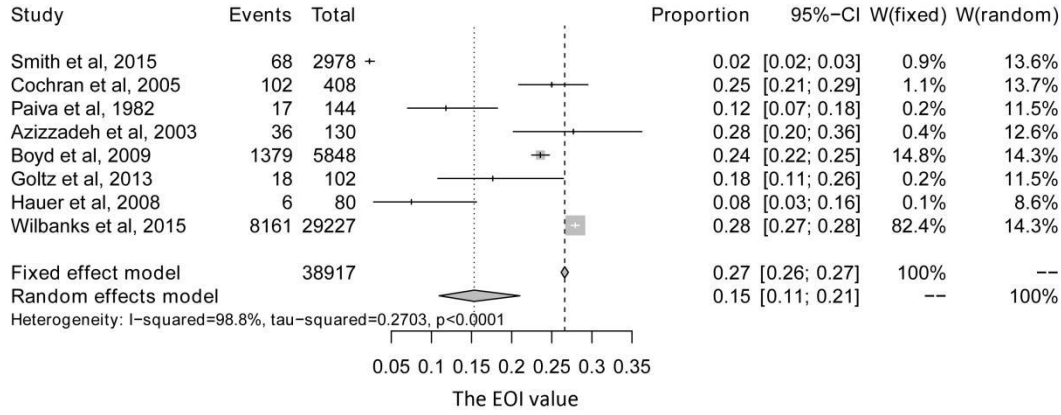
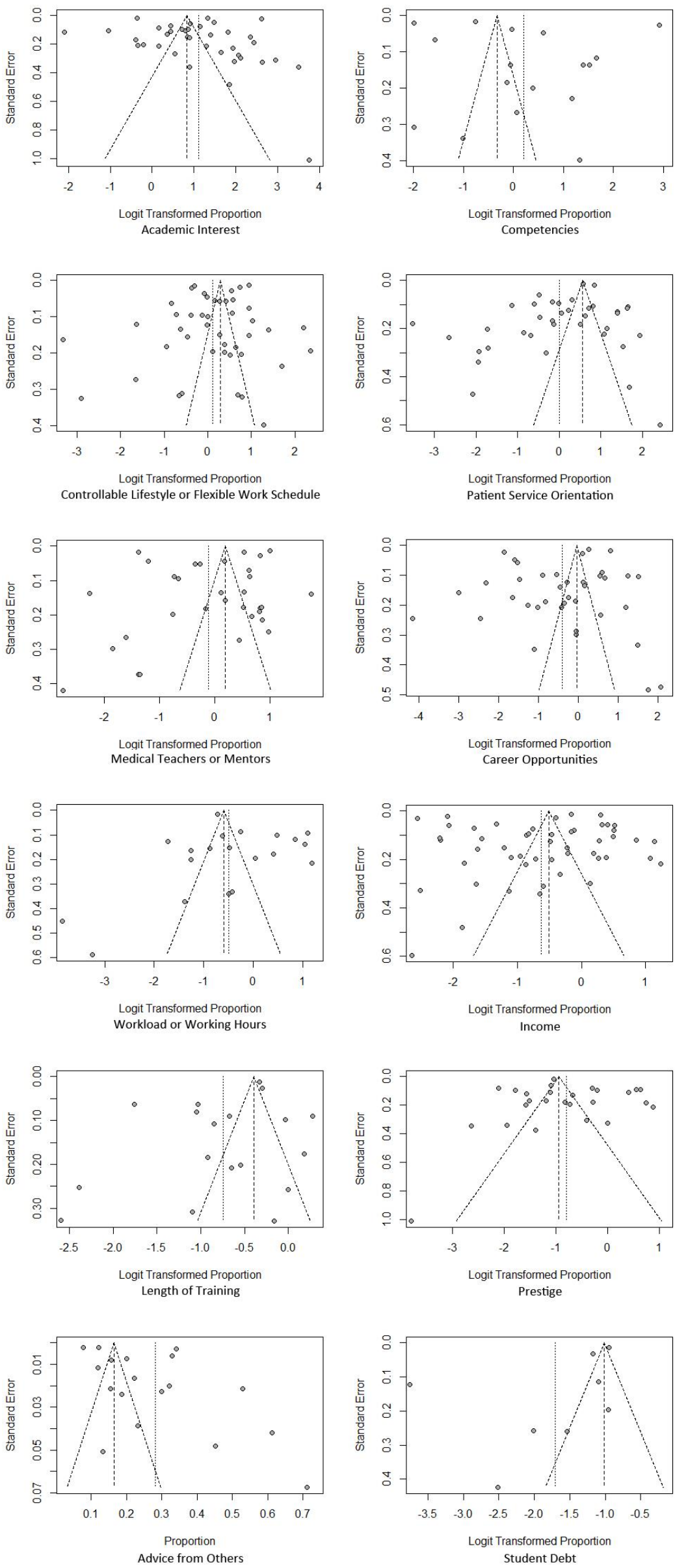


Figure S14. Funnel Plots of the Publication Bias Testing of the 12 Factors.



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5, 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7-8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

MOOSE Checklist for Meta-analyses of Observational Studies

Item No	Recommendation	Reported on Page No
Reporting of background should include		
1	Problem definition	5
2	Hypothesis statement	5
3	Description of study outcome(s)	5
4	Type of exposure or intervention used	5
5	Type of study designs used	5
6	Study population	5
Reporting of search strategy should include		
7	Qualifications of searchers (eg, librarians and investigators)	6
8	Search strategy, including time period included in the synthesis and key words	5
9	Effort to include all available studies, including contact with authors	5
10	Databases and registries searched	5
11	Search software used, name and version, including special features used (eg, explosion)	6
12	Use of hand searching (eg, reference lists of obtained articles)	5
13	List of citations located and those excluded, including justification	5-6
14	Method of addressing articles published in languages other than English	5
15	Method of handling abstracts and unpublished studies	5
16	Description of any contact with authors	5
Reporting of methods should include		
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	6
18	Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	6-7
19	Documentation of how data were classified and coded (eg, multiple raters, blinding and interrater reliability)	6-7
20	Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	6
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	6
22	Assessment of heterogeneity	6
23	Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	6-7
24	Provision of appropriate tables and graphics	5-7
Reporting of results should include		
25	Graphic summarizing individual study estimates and overall estimate	8
26	Table giving descriptive information for each study included	7
27	Results of sensitivity testing (eg, subgroup analysis)	8
28	Indication of statistical uncertainty of findings	7-9

Item No	Recommendation	Reported on Page No
Reporting of discussion should include		
29	Quantitative assessment of bias (eg, publication bias)	13
30	Justification for exclusion (eg, exclusion of non-English language citations)	13-14
31	Assessment of quality of included studies	13-14
Reporting of conclusions should include		
32	Consideration of alternative explanations for observed results	14
33	Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	14
34	Guidelines for future research	14
35	Disclosure of funding source	15

From: Stroup DF, Berlin JA, Morton SC, et al, for the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group. Meta-analysis of Observational Studies in Epidemiology. A Proposal for Reporting. *JAMA*. 2000;283(15):2008-2012. doi: 10.1001/jama.283.15.2008.

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Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Medical education and training
Keywords:	Medical students, Career choice, Meta-analysis

Title Page

Factors Influencing Subspecialty Choice Among Medical Students: A Systematic Review and Meta-analysis

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ABSTRACT

Objective To characterize the contributing factors that affect medical students' subspecialty choice and to estimate the extent of influence of individual factors on the students' decision-making process.

Design Systematic review and meta-analysis.

Methods A systematic search of the Cochrane Library, ERIC, Web of Science, CNKI and PubMed databases was conducted for studies published between January 1977 and June 2018. Information concerning study characteristics, influential factors, and the extent of their influence (EOI) was extracted independently by two trained investigators. EOI is the percentage level that describes how much each of the factors influenced students' choice of subspecialty. The recruited medical students include students in medical school, internship, residency training and fellowship, who are about to or have just made a specialty choice. The estimates were pooled using a random-effects meta-analysis model due to the between-study heterogeneity.

Results Data were extracted from 75 studies (882,209 individuals). Overall, the factors influencing medical students' choice of subspecialty training mainly included academic interests (75.29%), competencies (55.15%), controllable lifestyles or flexible work schedules (53.00%), patient service orientation (50.04%), medical teachers or mentors (46.93%), career opportunities (44.00%), workload or working hours (37.99%), income (34.70%), length of training

(32.30%), prestige (31.17%), advice from others (28.24%), and student debt (15.33%), with significant between-study heterogeneity (P<0.0001). Subgroup analyses revealed that the EOI of academic interests was higher in developed countries than that in developing countries (79.66% [95% confidence interval (CI), 70.73%; 86.39%] vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). The EOI value of prestige was lower in developed countries than that in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01).

Conclusions This systematic review and meta-analysis provided a quantitative evaluation of the top 12 influencing factors associated with medical students' choice of subspecialty. Our findings provide the basis for the development of specific, effective strategies to optimize the distribution of physicians among different departments by modifying these influencing factors.

Systematic review registration PROSPERO CRD42017053781.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study that provide a systematic estimate of the factors associated with medical students' subspecialty choices.
- A large number of studies conducted in varied populations have been included.
- The differences in the characteristics of country, survey years, specialty, the type of data used and sample size across studies represent a major limitation of our study.

KEYWORDS Medical students, career choice, meta-analysis

Introduction

Because of the population aging, increased workload on doctors through increased number of consultations and in managing patients with multi-morbidity, the demand for physicians continues to increase; however, an imbalance in the supply of physicians in different subspecialties has become a growing concern in both developed and developing countries.[1-5] Some specialties and subspecialties, such as family medicine and palliative medicine,[6 7] are experiencing a desperate shortage of physicians, whereas other specialties and subspecialties, such as cardiology, ophthalmology and ear, nose and throat (ENT) surgery, are highly competitive specialties with low success rate for candidates.[8 9]

Specialty choice is the product of a complex interconnection of student expectation, department expectation, and competition for available spots, and student choice is where the choice begins.[10] Previous studies have suggested that medical students' choice of subspecialty is essential to the maintenance of an adequate medical workforce and a balanced development of the medical system.[11 12] However, the influencing factors underlying students' subspecialty choice have not been systemically reviewed. Recent changes in the training and practice environment may influence medical students' career choice.[13] Additionally, the variability in preferences over time and in students' attitudes towards career choices can further complicate this assessment. For example, a study in the UK indicated that half of the medical students made a definitive subspecialty choice during their first year of medical school.[14] However, students were prone to changing their subspecialty preference during

medical school and internship.[15] Notably, students may also reject certain subspecialties during their medical school training, even those they have previously seriously considered.[16] Therefore, identifying the factors that influence students' choice of subspecialty will enable a better understanding of the current shortage/overload of physicians in specific fields and contribute to policy-building and decision-making to improve the training and recruitment of students in the future.

We thus conducted a systematic review and a meta-analysis to investigate the influencing factors and the extent of their influence on the choice of subspecialty training among medical students. More specifically, we focused on the following questions. First, can we gain a better understanding of students' preferences for medical specialty according to the primary influencing factor? Second, do the subgroups according to world region and survey years examined in this study differ significantly with regard to the weight that students place on the identified influencing factor?

Methods

We developed a review protocol (registration number: PROSPERO CRD42017053781) prior to commencing the study. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was used to ensure the reporting quality of this review **(Fig. S1)**.[17]

Search Strategy and Study Eligibility

We performed a literature search in June 2018 using the Cochrane Library, Medline,

Web of Science, CNKI and ERIC databases without language restrictions. Articles were screened by title, abstract and reference list, and by correspondence with study investigators. Potentially relevant papers were first identified by reviewing the titles and abstracts, and the full text of each retrieved article was then assessed. A detailed example of search strategy for Medline/PubMed is shown in **Methods S1**. Studies were included if they were systematic review or cross-sectional studies, reported data on medical students, were published in peer-reviewed journals, and used a validated method to assess the EOI on the choice of subspecialty, such as pediatric gastroenterology and vascular surgery, or its corresponding specialty, such as pediatrics and surgery. Because of the differences between medical education systems in the world, the medical students we recruited includes the student in medical school, internship, residency training and fellowship, containing the students who about to make a specialty choice and students who has just made a specialty choice. A guide to medical specialty, available at https://www.abms.org/member-boards/specialty-subspecialty-certificates/, were used to identify the medical specialty and subspecialty of our research. We also conducted an additional search using OpenGrey. However, no additional articles were further included. All searches were performed using Google chrome (version 54.0.2840).

Data Extraction and Quality Assessment

Each article was reviewed by two trained investigators (Y.Y. and J.L.) and the following information was independently extracted from each selected article using a standardized form: study design, geographic location, years of survey, journal, sample

size, average age of the participants, the number and percentage of male participants, and the influencing factors and the extent of their influence. A third investigator was consulted if disagreements occurred. Each study may involve one or several influencing factors. An 11-item checklist which was recommended by Agency for Healthcare Research and Quality (AHRQ), used for cross-sectional studies [18], available at https://www.ncbi.nlm.nih.gov/books/NBK35156/, were used to assess the quality of the studies. All discrepancies were resolved via discussion and consensus.

Statistical Analysis

As considerable heterogeneity was expected because of the multiple sources of variances, a random effects meta-analysis model was used to estimate the influencing factors and the extent of their influence.[19] Between-study heterogeneity was assessed using the Cochran's Q-test, and was quantified with the I^2 statistic, which was calculated to describe the percentage of total variation caused by heterogeneity across studies, with ≥50% indicating considerable heterogeneity. [20 21] Potential sources of heterogeneity were identified using meta-regression.[22] Four categorical covariates were defined as potential sources of heterogeneity by examining the studies conducted in the United States (US) vs. the studies conducted in other countries, the studies conducted before 2010 vs. those conducted after 2010, the studies concerning subspecialty only vs. those that were not specific to a subspecialty, and the studies with a sample size <200 vs. the studies with a sample size ≥200. Subgroup analyses were performed for each factor in the studies in developed countries vs. developing countries and studies conducted before 2010 vs. after 2010. The EOI value of competencies in

developing countries was not statistically significant (81.21% [95% CI, 75.27%; 86.51%], P=0.1436), and no studies on the influence of student debt in developing countries were found. The Q-test based on the analysis of variance was used to compare the subgroups, with a significance threshold of 5%.[23] The influence of individual studies on the overall EOI value was explored by serially excluding each study in a sensitivity analysis. Publication bias was investigated using a funnel plot test and Egger's test.[24 25] Fill and trim approach, which imputes estimates from hypothetical negative unpublished reports,[26] was also used to investigate the publication bias if the Egger's test was significant. All analyses were performed using R (version 3.3.1, The R Foundation, Vienna, Austria). The statistical tests were 2-sided with a significance threshold of P<0.05.

Patient and public involvement: Patients and the public were not involved in development of the research question and outcome measures, nor the study design. The study does not involve patient recruitment, and patients were not involved in conduct of the study. We plan to liaise closely with patients, special interest groups, and charities in the dissemination of our results in printed and electronic media.

Results

Study Characteristics

Seventy-five cross-sectional studies involving a total of 882,209 individuals that published between January 1977 and May 2018 were included in the present research **(Table 1).** Thirty-four studies were conducted in North America, 24 in Europe, 7 in

Asia, 5 in Oceania, 3 in Africa, and 2 in South America. The median number of participants per study was 243 (range 37-29,227). Fourteen studies included students who had already selected subspecialties, whereas 61 did not. The influencing factors were ranked according to the frequency of occurrence and each factor was identified when at least 5 papers were available describing it. The influencing factors for subspecialty choice were then classified according to 17 aspects, including academic interests, controllable lifestyle or flexible work schedule (defined as flexibility that allows physicians to control the number of hours devoted to practicing the specialty), competencies, patient service orientation, medical teachers or mentors, career opportunities, workload or working hours (characterized by the physician's time spent on professional responsibilities), income, prestige, length of training, advice from others (advice from family, friends, and other students), student debt, experience with the subject, working environment, personality, gender and job security. Personality and gender are common factors that affect the choice of subspecialty among medical students, but most of the relevant literature has not reported on the extent of these factors' influence. Moreover, the funnel plots were clearly asymmetrical with regard to experience with the subject, the working environment and job variety, indicating the existence of publication bias. Thus, the analysis of the remaining 12 influencing factors were shown in this paper. Studies assessed for influencing factors using questionnaires validated to medical students asking the extent of certain factors the studies investigated. Quality assessment scores for the included studies are listed in **Table 1**. None of the studies received a point for the second AHRQ Quality Indicator, which requires studies to list the inclusion and exclusion criteria for exposed and unexposed

subjects (cases and controls) or refer to previous publications, since no comparison studies were referenced in the analyzed articles. For the remaining 10 criteria, 6 studies received 9 points, 8 studies received 8 points, 17 studies received 7 points, 33 studies received 6 points, 9 studies received 5 points and 2 studies received 4 points (scores for individual studies are presented in **Table S1**).

Primary Analysis

A meta-analysis was performed on the 12 influencing factors **(Table 2)**: academic interests **(Fig. S2)**, competencies **(Fig. S3)**, controllable lifestyle or flexible work schedule **(Fig. S4)**, patient service orientation **(Fig. S5)**, medical teachers or mentors **(Fig. S6)**, career opportunities **(Fig. S7)**, workload or working hours **(Fig. S8)**, income **(Fig. S9)**, length of training **(Fig. S10)**, prestige **(Fig. S11)**, advice from others **(Fig. S12)** and student debt **(Fig. S13)**. All the factors were significant with evidence of between-study heterogeneity ($P<0.0001$). A sensitivity analysis, in which the meta-analysis was serially repeated after the exclusion of each study, demonstrated that no individual study affected the overall extent of a factor's influence.

Meta-regression and Subgroup Analysis

We performed meta-regression to identified the potential sources of heterogeneity using common instructions when at least 5 studies were available and at least 2 studies were in each comparator subgroup **(Table 3).** Some of the heterogeneities observed among the 12 factors can be partially explained by country, survey years, specialty and sample size.

EOI values were further analyzed by subgroup **(Table S2)** according to world region **(Fig. 1)** and survey year **(Fig. 2).** The EOI value of academic interests in developed countries was higher than that in developing countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02). Conversely, a lower EOI value of prestige was found in studies conducted in developed countries than in developing countries (23.96% [95% CI, 19.20%; 29.47%] vs. 47.65% [95% CI, 34.41%; 61.24%]; Q=4.71 P=0.01). No statistically significant subgroup differences in the EOI values of the other influencing factors were noted between developed countries and developing countries**.** In addition, no statistically significant differences in the EOI values of the influencing factors were observed when subgroup analysis was performed by survey year.

Assessment of Publication Bias

We generated a funnel plot with proportion as the abscissa and standard error as the ordinate. A visual inspection of the funnel plots revealed minimal asymmetry among the various influencing factors **(Fig. S14)**, and the results were concentrated in the narrow upper part of the graph. There was evidence of small study effect in the meta-analysis of "patient service orientation" (Egger's test P=0.02). However, the trim-and-fill method showed the publication-bias corrected estimate remained statistically significant (63.79%, 95% CI, 58.20%; 69.04%).

Discussion

Implications

This systematic review and meta-analysis involved 75 studies with 882,209 medical students. Twelve influencing factors were analyzed. These factors can be classified into two categories: economic factors and non-economic factors. We found that the EOI of the economic factors, including income (34.70%) and student debt (15.33%), may not depend on the region's level of economic development. However, income remained a major influencing factor in the process of choosing a specialty or subspecialty. In the US, 15% of full-time family medicine physicians earned less than $100,000 in 2004, which is significantly less than the income earned by invasive cardiologists (median income=$427,815), neurosurgeons (median income=$211,094), and orthopedists (median income=$335,646).[27] This economic inequality made family medicine less attractive to medical school graduates.[28] Benefits such as health insurance and tuition reimbursement have been shown to be the most common economic incentives used to attract applicants.[29]

The non-economic factors can be divided into individual factors, specialty-related factors and others. First, individual factors, including academic interest and competencies, have a considerable impact on students' subspecialty choice, with EOI values of 75.29% and 55.15%, respectively. In addition, in the subgroup analysis, although academic interests were less influential in developing countries than in developed countries (79.66% [95% CI, 70.73%; 86.39% vs. 60.41% [95% CI, 43.44%; 75.19%]; Q=3.51 P=0.02), they were still the most influential of the 12 factors regardless of regional economic level. These findings indicate that subspecialties with a shortage of manpower may attract more students by increasing students' interests and

improving the quality of education. Previous studies indicated that early specialty exposure in medical education may arouse students' academic interest and improve their clinical competence.[28 30] For example, an elective extracurricular program designed to facilitate early contact with family medicine physicians was found to significantly improve students' interest and clinical skills, especially communication skills, in family medicine.[31] Furthermore, dispelling myths and espousing the positive aspects of a discipline may provide a better understanding of certain specialties; this approach could also be effective in increasing students' academic interest.[32] For instance, family medicine is often considered a discipline that requires less professional skills and knowledge. This misconception demotivates students from choosing family medicine as their future career specialty, and this trend may eventually lead to a shortage of family physicians.[32] Eliminating such prejudices may help students pay greater attention to the areas in short supply and restore their interests in other specialties.

Second, the specialty-related factors included controllable lifestyle/flexible work schedule (EOI of 53.00%), career opportunities (EOI of 44.00%), workload (EOI of 37.99%) and training length (EOI of 32.30%). Of these factors, lifestyle varied between different areas. Additionally, although certain specialties, such as general surgery, seem to have an adequate number of surgeons on a per capita basis in the US, there is still a poor geographic distribution within the surgical workforce according to the type of surgical practice.[33] The inflexible lifestyle is a common reason that students perceive surgery to be less attractive.[33] Reorganization of expected work hours within shared

practices and the increased use of physician extenders and technologies such as electronic medical records may give physicians more flexibility in work schedules.[34] Moreover, providing promotion opportunities and shortening the length of training are possible strategies to recruit new staff in subspecialties that require a long period of post-graduate residency training, such as neurosurgery.[35]

Finally, other factors such as service orientation (EOI of 50.74%), medical teachers or mentors (EOI of 46.93%), prestige (EOI of 34.68%), and advice from others (EOI of 28.24%) also contribute to the decision-making process of medical students. For example, the desire to care for patients with end-stage diseases contributed to the decision to enter palliative medicine in 86% of the medical students.[7] Additionally, exposure to mentors in a particular clinical field such as internal medicine has been strongly associated with medical students' choice of clinical field.[36] Moreover, improving the occupational prestige of areas such as family medicine, pathology, and radiology may help reshape the distribution of the workforce. [30 37 38]

In our study, several findings are especially noteworthy. First, interest was far more important than income in deciding subspecialty. In our study, interest was the top-ranked influencing factor (EOI of 75.29%) of subspecialty choice, while income was ranked lower (EOI of 34.70%). This finding argues against the possible default belief that raising physician's wages alone could solve the uneven distribution of clinicians among subspecialties. Our findings highlight that cultivating and stimulating students' professional interests may help improve the maldistribution of medical resources in a more efficient and cost-saving manner.

Second, improving abilities in a certain subspecialty of interest can greatly affect medical students' professional choice. In our study, competencies ranked second in influence, which may reflect the impact of admission conditions on students' choice of subspecialty. Hence, to reduce the risk that students are restricted to the subspecialty of their interest due to a lack of personal skills, medical education should focus more on enhancing students' personal competencies in addition to their academic interests.

Third, balancing medical resources is a complex process in practical terms, as the influencing factors are not mutually exclusive. The shortage of physicians in certain subspecialties may increase physician workload, resulting in less time for teaching. Hence, the quality of teaching cannot be guaranteed, and students may tend to avoid choosing these subspecialties, thus worsening the imbalance in the medical workforce. Additionally, some of the 12 factors identified are not amenable to practical interventions. For example, prestige cannot be immediately increased using interventional strategies.[37] Overall, effective strategies must be multi-pronged and incorporate several different aspects, and maldistribution in the workforce should not be tackled through a simple adjustment of one influencing factor.

Interpretations of the results of this meta-analysis

Our meta-regression stratified by the study-level characteristics found that country, survey years, subspecialty and sample size may contribute to the heterogeneity between studies. There was no significant difference in the sensitivity analysis, which indicated that the results of the meta-analysis were convincing. The funnel plots and Egger's tests revealed that most of the publication bias was small (P>0.05), except for

the meta-analysis of "patient service orientation". Moreover, the majority of the studies collected in the database were from developed countries rather than developing countries.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the students involved in our study included medical students at different stages of their medical education. Students' perception about different subspecialties may change during medical training until the students applies for specialty training. For example, compared to an intern, a freshman student may place greater emphasis on income and prestige when considering a career choice.[39] A subgroup analysis stratified by the stages of medical education and a secondary meta-analysis of longitudinal studies may better reflect changes in influencing factors and the extent of their influence over time. Second, our meta-analysis summarized the data from different geographic regions around the world, and the general conclusions may not be appropriate to guide policy development in each region. Enhanced effort is needed to develop specific intervention strategies according to the specific economic level, religious beliefs, healthcare system, educational system and endemic diseases of different countries and regions. Subgroup analysis stratified by organizational and medical training factors would provide more information of the factors influencing subspecialty choice among medical students. Third, the surveys in the various studies were also conducted using different methods. Most of the questionnaires used a Likert scale. Therefore, when we converted the results to a percentage representing the extent

of a factor's influence, the Likert scale items were treated as interval data.[40-42] Consequently, there may have been differences in the conversion process. Finally, the analysis relied on aggregated published data. A multicenter prospective study would provide more accurate estimate of the influencing factors and the extent of their influence on medical students' choice of subspecialty.

Conclusion

In conclusion, this systematic review and meta-analysis provided a summary evaluation of 12 influencing factors and the extent of their influence on the choice of subspecialty training among medical students. Understanding students' attitudes toward their subspecialty decision-making process could provide the basis for developing strategies to increase the attractiveness of subspecialties experiencing a shortage of manpower, thereby balancing the distribution of medical recourses.

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Data sharing: Extracted data are available upon request to the corresponding author.

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Legends

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Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

Supplements

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Figure S8. Forest Plot of "Workload or Working Hours".

Figure S9. Forest Plot of "Income".

Figure S10. Forest Plot of "Length of Training".

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Figure S12. Forest Plot of "Advice from Others".

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Figure S14. Funnel Plots of the Publication Bias Tests of the 12 Factors.

Table 1. Selected Characteristics of the 75 Studies Included in this Systematic Review and Meta-analysis

First Author, Year	Country	Survey years	Sample size	Average age	Men, No. (%)	Scores
Smith et al,[43] 2015	UK	2012	2,978	NR	NR	6
Cochran et al,[44] 2005	USA	2002	408	27.2	214 (52.45)	5
Hauer et al,[45] 2008	USA	2007	1,177	NR	NR	6
Johnson et al,[46] 2012	USA	2012	622	NR	NR	6
Kiolbassa et al,[47] 2011	Germany	2010	1,114	24.1	408 (36.62)	5
Klingensmith et al,[48] 2015	USA	2013	792	NR	539 (68.06)	6
Lee et al,[49] 2012	USA	2012	100	NR	58 (58)	7
Macdonald et al,[50] 2012	New Zealand	2011	134	NR	79 (58.96)	7
Parsa et al,[39] 2010	Iran	2006-2007	137	27.34	49 (35.77)	7
Paiva et al,[51] 1982	USA	1982	144	NR	NR	6
Ni Chroinin et al,[52] 2013	UK	2009-2011	274	NR	112 (40.89)	7
Newton et al,[34] 2005	USA	1998-2004	1,258	NR	642 (51.03)	8
Rogers et al,[53] 1990	USA	1989	266	NR	205 (77.07)	6
Abendroth J et al,[54] 2014	Germany	2007-2012	45	NR	14 (31)	7
Alawad et al,[55] 2015	USA	2010-2011	45	NR	36 (80)	8
Azizzadeh et al,[56] 2003	USA	2002	130	NR	NR	6
Celenza et al,[57] 2012	Australia	2009	216	NR	121 (56.02)	8
Dolan-Evans et al,[58] 2014	Australia	2013	419	NR	215 (51.31)	8
Boyd et al,[59] 2009	USA	2005-2006	5,848	NR	2,982 (50.99)	8
Egerton et al,[60] 1985	Ireland	1977-1981	134	30	82 (61.19)	6
Diderichsen et al,[61] 2013	Sweden	2006-2009	372	27	157 (42.20)	6
Ferrari et al,[62] 2013	Italy, UK	2009-2011	45	25	NR	9
Freire et al,[63] 2011	Brazil	2006-2008	290	23	102 (35.17)	7
Buddeberg-Fischer et al,[64] 2006	Switzerland	2001-2003	522	31.1	241 (46.17)	9
Dorsey et al,[65] 2005	USA	2003	11,029	NR	4,964 (45.01)	6
Ekenze et al,[66] 2013	Nigeria	2009-2010	96	25.9	NR	7
Barikani et al,[67] 2012	Australia	2008-2009	49	21.7	NR	6
Bittaye et al,[68] 2012	Gambia	2011	106	24.1	48 (45.28)	6
Bonura et al,[69] 2016	USA	2015	590	NR	321 (54.40)	9
Al-Fouzan et al,[70] 2012	Kuwait	2011-2012	144	NR	NR	7
AlKot et al,[71] 2015	Egypt	2013	451	21.8	NR	7
Borges et al,[72] 2009	USA	2001-2005	341	NR	NR	5
Budd et al,[73] 2011	UK	2011	870	22	NR	7
Corrigan et al,[74] 2007	Ireland	2007	222	NR	142 (63.96)	7
Davis et al,[75] 2016	UK	2016	173	NR	76 (43.93)	7

Deutsch et al,[76] 2015	Germany	2011	659	27.9	NR	8
Gardner et al,[77] 2014	Australia	1993-2005	631	NR	NR	7
Dias et al,[78] 2013	UK	2013	495	NR	438 (88.48)	5
Goltz et al,[79] 2013	USA	2012	102	24.5	34 (33.33)	6
Gupta et al,[80] 2013	India	2013	243	NR	179 (73.36)	6
Hanzlick et al,[81] 2008	USA	2006	161	NR	NR	6
Harris et al,[82] 2005	USA	1991-2002	104	NR	53 (50.96)	6
Hauer et al,[83] 2008	USA	2008	80	NR	NR	6
Labiris et al,[84] 2014	Greece	2014	111	23.6	55 (49.54)	6
Lambert et al,[85] 2008	UK	2007	17,393	NR	NR	6
Shah et al,[86] 2012	USA	2011	892	NR	NR	6
Lefevre et al,[87] 2010	USA	2008	1,555	NR	589 (37.88)	6
Vicente et al,[88] 2013	Chile	2013	30	NR	NR	6
Wiesenfeld et al,[89] 2014	Canada	2013	60	NR	NR	7
Lam et al,[90] 2016	Hong Kong	2015	228	23	NR	9
Hartung et al,[91] 2005	USA	2004	192	20.59	74 (38.54)	4
Girasek et al,[92] 2011	Hungary	2011	536	NR	NR	5
Zuccato et al,[93] 2015	Canada	2012	37	NR	24 (65)	6
Wilbanks et al,[94] 2015	USA	2011-2013	29,227	NR	15,164 (51.99)	9
West et al,[95] 2009	USA	2005-2007	14,890	NR	8,700 (58.43)	6
Watmough et al,[96] 2007	UK	2005	116	NR	66 (56.90)	4
Thakur et al,[97] 2001	USA	2001	56	NR	53 (95)	8
Scott et al,[98] 2011	Canada	2002-2004	1,542	NR	NR	6
Schnuth et al,[99] 2003	USA	2002	203	NR	72 (53.47)	6
Richards et al,[100] 2009	UK	2009	150	NR	108 (72.00)	5
Reed et al,[101] 2009	USA	2008	2,022	NR	1,354 (66.96)	9
de Souza et al,[102] 2015	Portugal	2012	1,303	NR	NR	7
Pikoulis et al,[103] 2010	Greece	2006-2007	87	NR	NR	6
Ozer et al,[104] 2015	Turkey	2013	98	27.7	26 (26.53)	6
Noble et al,[105] 2004	Canada	2004	21,296	NR	NR	8
Noble et al,[106] 2010	Canada	2007	120	NR	NR	5
Newton et al,[107] 2005	USA	2004	1,286	NR	NR	6
Moore et al,[108] 2012	USA	2011	337	26	179 (53.12)	6
Momen et al,[109] 2015	Iran	2014-2015	38	35.6	11 (29)	6
Mehmood et al,[110] 2012	Saudi Arabia	2012	550	NR	348 (63.27)	6
Loriot et al,[111] 2010	France	2007	44	NR	17 (39)	7
Lefevre et al,[112] 2010	France	2008	522	23.8	198 (37.93)	7
Vo et al,[113] 2017	Canada	2017	90	22.5	52 (57.78)	5
Grasreiner et al,[114] 2018	Germany	2014-2016	181	24	33 (18.10)	6
Alkhannen et al,[115] 2018	Saudi Arabia	2017	436	NA	250 (57.00)	5

Footnotes: scores: quality score of the AHRQ scale.

Table 2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty

Factor	No. of studies	Total no. of participants	EOI value (%)	95 CI% of EOI value		*Cochran's Q*	*I-square* (%)	*Tau-square*	*P*-Value
				Lower	Upper				
Academic interests	38	82,366	75.29	66.93	82.11	14719.76	99.70	1.60	<0.0001
Competencies	17	76,515	55.15	33.63	74.90	23572.74	99.90	3.44	<0.0001
Controllable lifestyle or flexible work schedule	44	101,001	53.00	47.90	58.03	8624.46	99.50	0.45	<0.0001
Patient service orientation	37	46,572	50.04	44.65	55.43	2668.79	98.70	0.41	<0.0001
Medical teachers or mentors	32	85,071	46.93	37.77	56.30	15216.32	99.80	1.14	<0.0001
Career opportunities	38	81,923	44.00	32.26	48.78	13553.20	99.70	1.15	<0.0001
Workload or working hours	20	22,051	37.99	29.59	47.19	584.81	98.30	0.69	<0.0001
Income	50	109,791	34.70	28.36	41.62	16952.48	99.70	1.09	<0.0001
Length of training	18	42,046	32.30	27.61	37.37	917.21	98.10	0.20	<0.0001
Prestige	26	30,629	31.17	26.32	37.69	1464.67	98.30	0.52	<0.0001
Advice from others	18	82,692	28.24	22.26	34.23	7679.73	99.80	0.02	<0.0001
Student debt	8	38,917	15.33	10.96	21.03	574.81	98.80	0.27	<0.0001

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Table 3. Meta-regression of the EOI Value Stratified by Study-level Characteristics

Factor		estimate	95 CI% of estimate		*P*-Value
			Lower	Upper	
Academic interests	Country	-0.2314	-1.1575	0.6946	0.6302
	Survey years	0.3811	-0.3580	1.1202	0.2711
	Specialty	-0.4892	-1.5345	0.5562	0.4008
	Sample size	0.2362	-0.5488	1.0212	0.6537
Competencies	Country	0.6946	-1.1461	0.8938	0.8376
	Survey years	-1.0418	-2.0950	0.0114	0.0151
	Specialty	0.0904	-1.5786	1.7594	0.9398
	Sample size	-0.5720	-1.8606	0.7166	0.5823
Controllable lifestyle or flexible work schedule	Country	-0.1261	-1.1461	0.8938	0.9614
	Survey years	-0.0001	-0.4052	0.4051	0.9822
	Specialty	-0.8989	-1.4979	-0.3000	0.0035
	Sample size	-0.0518	-0.4396	0.3361	0.7203
Patient service orientation	Country	-0.6238	-1.3118	0.0642	0.0833
	Survey years	-0.0414	-0.6912	0.6083	0.8524
	Specialty	-1.5982	-2.5227	-0.6737	0.0010
	Sample size	-0.1157	-0.7473	0.5159	0.6358
Medical teachers or mentors	Country	0.7395	0.3117	1.1674	0.0007
	Survey years	0.1133	-0.3580	0.5845	0.6376
	Specialty	0.0605	-0.4441	0.5652	0.8141
	Sample size	-0.1202	-0.5567	0.3163	0.5894
Career opportunities	Country	0.1075	-0.7030	0.9179	0.5828
	Survey years	0.3284	-0.3913	1.0480	0.7546
	Specialty	-0.9292	-1.8015	-0.0570	0.0077
	Sample size	0.3654	0.1156	1.5478	0.0081
Workload or working hours	Country	-0.4535	-1.5086	0.6016	0.3981
	Survey years	0.4624	-0.5417	1.4665	0.3922
	Specialty	-0.9878	-2.1727	0.1972	0.1070
	Sample size	0.0982	-0.8589	1.0553	0.8205
Income	Country	0.1058	-0.4665	0.6781	0.7390
	Survey years	0.0999	-0.4379	0.6377	0.8774
	Specialty	-0.6457	-1.3267	0.0352	0.0480
	Sample size	0.0523	-0.4826	0.5872	0.6786
Length of training	Country	-0.1559	-1.2782	0.9664	0.7854
	Survey years	-0.2158	-1.4089	0.9772	0.7229
	Specialty	0.3959	-0.9585	1.7502	0.5667
	Sample size	0.1565	-0.6631	0.9761	0.7082

Prestige	Country	-0.3346	-1.0799	0.4106	0.3485
	Survey years	-0.4513	-1.1378	0.2352	0.0950
	Specialty	-1.0112	-1.8980	-0.1244	0.0172
	Sample size	0.0355	-0.6013	0.6723	0.5214
Advice from others	Country	-0.0097	-0.0722	0.0529	0.9328
	Survey years	-0.0861	-0.1471	-0.0251	0.0057
	Specialty	-0.2017	-0.2790	-0.1244	<0.0001
	Sample size	0.2125	0.1309	0.2941	<0.0001
Student debt	Country	2.7853	2.0544	3.5162	0.0001
	Survey years	-0.1567	-0.6707	0.3573	0.5502
	Sample size	-0.5248	-1.0108	-0.0388	0.0343

736

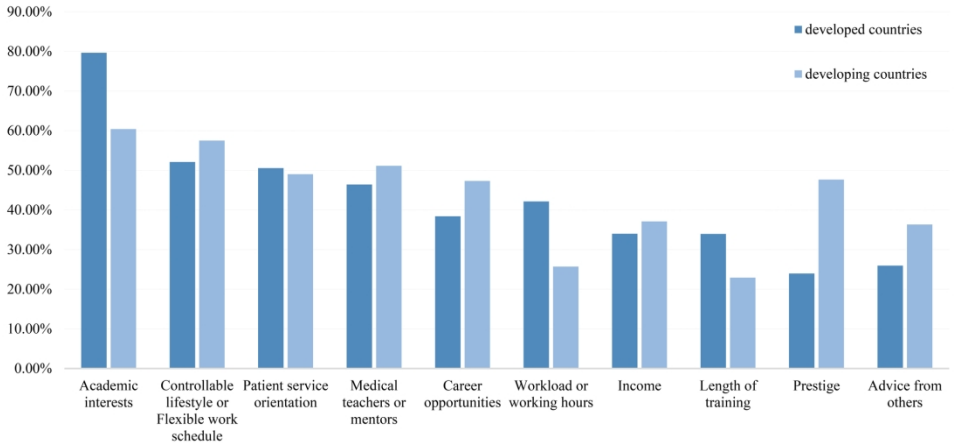


Figure 1. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region.

190x107mm (300 x 300 DPI)

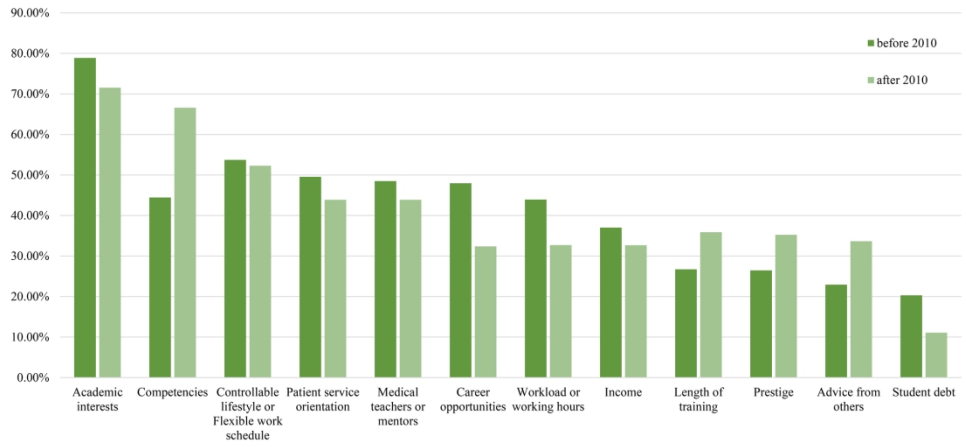


Figure 2. Bar Graph of the Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Survey Year.

190x107mm (300 x 300 DPI)

SI Methods. Search strategy used in the current systematic review and meta-analysis.

Medical Students

1. Students, Medical [Mesh]
2. Medical students
3. Medical student
4. Student, Medical
5. OR / 1 – 4

Subspecialty Choice

6. Career choices
7. Choice, Career
8. Choices career
9. Specialties
10. Sub-specialties
11. Sub-discipline
12. OR / 6 – 11

Study design

13. Cross sectional study
14. Cross sectional study [Publication Type]
15. Cross sectional study [Mesh Terms]
16. Systematic review
17. Systematic review [Publication Type]
18. Systematic review [Mesh Terms]
19. Meta-analysis [Title/Abstract]
20. Meta-analysis [Mesh Terms]
21. Meta-analysis [Publication Type]
22. OR / 12 – 21

Factors

23. Factors

Combined search

23. #5 AND #12AND #22 AND #2

Abbreviations: MeSH, Medical Subject Heading in PubMed

Table S1. Quality assessment of the included studies

	Quality assessment criteria	1	2	3	4	5	6	7	8	9	10	11	Scores
1	Smith et al,[41] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
2	Cochran et al,[42] 2005	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
3	Hauer et al,[43] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
4	Johnson et al,[44] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
5	Kiolbassa et al,[45] 2011	Y	U	Y	Y	N	Y	N	Y	N	N	N	5
6	Klingensmith et al,[46] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
7	Lee et al,[47] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
8	Macdonald et al,[48] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
9	Parsa et al,[37] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
10	Paiva et al,[49] 1982	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
11	Ni Chroinin et al,[50] 2013	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
12	Newton et al,[32] 2005	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
13	Rogers et al,[51] 1990	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
14	Abendroth J et al,[52] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	Y	7
15	Alawad et al,[53] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	N	8
16	Azizzadeh et al,[54] 2003	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
17	Celenza et al,[55] 2012	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
18	Dolan-Evans et al,[56] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	Y	8
19	Boyd et al,[57] 2009	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
20	Egerton et al,[58] 1985	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
21	Diderichsen et al,[59] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
22	Ferrari et al,[60] 2013	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
23	Freire et al,[61] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
24	Buddeberg-Fischer et al,[62] 2006	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
25	Dorsey et al,[63] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
26	Ekenze et al,[64] 2013	Y	U	Y	Y	Y	Y	Y	N	N	Y	N	7
27	Barikani et al,[65] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
28	Bittaye et al,[66] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
39	Bonura et al,[67] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
30	Al-Fouzan et al,[68] 2012	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
31	AlKot et al,[69] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
32	Borges et al,[70] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
33	Budd et al,[71] 2011	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
34	Corrigan et al,[72] 2007	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
35	Davis et al,[73] 2016	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
36	Deutsch et al,[74] 2015	Y	U	Y	Y	Y	Y	N	Y	Y	Y	N	8
37	Gardner et al,[75] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	7
38	Dias et al,[76] 2013	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
39	Goltz et al,[77] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
40	Gupta et al,[78] 2013	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
41	Hanzlick et al,[79] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
42	Harris et al,[80] 2005	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
43	Hauer et al,[81] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
44	Labiris et al,[82] 2014	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
45	Lambert et al,[83] 2008	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
46	Shah et al,[84] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
47	Lefevre et al,[85] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
48	Vicente et al,[86] 2013	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
49	Wiesenfeld et al,[87] 2014	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
50	Lam et al,[88] 2016	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
51	Hartung et al,[89] 2005	Y	U	Y	Y	N	Y	N	N	N	N	N	4
52	Girasek et al,[90] 2011	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
53	Zuccato et al,[91] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
54	Wilbanks et al,[92] 2015	Y	U	Y	Y	N	Y	Y	Y	Y	Y	Y	9
55	West et al,[93] 2009	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
56	Watmough et al,[94] 2007	Y	U	Y	Y	N	N	N	N	N	Y	N	4
57	Thakur et al,[95] 2001	Y	U	Y	Y	Y	Y	Y	N	Y	Y	N	8
58	Scott et al,[96] 2011	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
59	Schnuth et al,[97] 2003	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
60	Richards et al,[98] 2009	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
61	Reed et al,[99] 2009	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	N	9
62	de Souza et al,[100] 2015	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
63	Pikoulis et al,[101] 2010	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
64	Ozer et al,[102] 2015	Y	U	Y	Y	N	N	Y	N	Y	Y	N	6
65	Noble et al,[103] 2004	Y	U	Y	Y	Y	Y	Y	Y	N	Y	N	8
66	Noble et al,[104] 2010	Y	U	Y	Y	N	Y	N	N	N	Y	N	5
67	Newton et al,[105] 2005	Y	U	Y	Y	N	Y	Y	N	N	Y	N	6
68	Moore et al,[106] 2012	Y	U	Y	Y	Y	Y	N	Y	N	N	N	6
69	Momen et al,[107] 2015	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
70	Mehmood et al,[108] 2012	Y	U	Y	Y	N	Y	N	Y	N	Y	N	6
71	Loriot et al,[109] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
72	Lefevre et al,[110] 2010	Y	U	Y	Y	Y	Y	N	Y	N	Y	N	7
73	Vo et al,[111] 2017	Y	U	Y	Y	Y	N	N	N	N	Y	N	5
74	Grasreiner et al,[112] 2018	Y	U	Y	Y	Y	Y	N	N	N	Y	N	6
75	Alkhannen et al,[113] 2018	Y	U	Y	Y	N	N	Y	N	N	Y	N	5

Quality assessment criteria in detail

1. Define the source of information (survey, record review).

2. List the inclusion and exclusion criteria for the exposed and unexposed subjects (cases and controls) or refer to previous publications.

3. Indicate the time period used for identifying patients.

4. Indicate whether the subjects were consecutive if not population-based.

5. Indicate whether the evaluators of the subjective components of the study were masked to the other aspects of participants' status.

6. Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)

7. Explain any patient exclusion from the analyses.

8. Describe how confounding was assessed and/or controlled.

9. If applicable, explain how missing data were handled in the analysis.

10. Summarize the patient response rates and the completeness of the data collection.

11. Clarify what follow-up, if any, was expected and the percentage of patients with incomplete data or follow-up.

"Y": Yes; "N": No; "U": Unclear.

Table S2. Meta-analyses of the Factors Influencing Medical Students' Choice of Subspecialty Stratified by Region and Survey Year.

Factor		No. of studies	Total no. of participants	Extent of influence (%)	95 CI% of EOI value		*I-square* (%)	*P*-Value	*Q*-Value
					Lower	Upper			
Academic interest	developed	28	80,000	79.66	70.73	86.39	99.8	0.02	3.51
	developing	10	2,366	60.41	43.44	75.19	98.0		
	before 2010	29	44,174	78.88	69.04	86.22	99.7	0.40	1.21
	after 2010	9	38,192	71.54	57.66	82.27	99.6		
Competencies	before 2010	9	43,134	44.40	29.11	60.83	99.8	0.21	1.86
	after 2010	8	33,381	66.60	34.48	88.31	99.8		
Controllable lifestyle or flexible work schedule	developed	37	100,980	52.11	46.52	57.65	99.6	0.63	0.68
	developing	7	2,017	57.50	45.81	68.41	95.9		
	before 2010	22	62,945	53.72	47.48	59.84	99.4	0.97	0.05
	after 2010	22	40,056	52.29	43.51	60.93	99.2		
Patient service orientation	developed	27	44,235	50.56	44.68	56.42	98.8	0.74	0.48
	developing	10	2,337	49.02	31.62	66.67	98.1		
	before 2010	18	40,997	49.56	43.29	55.84	98.8	0.70	0.54
	after 2010	19	5,579	43.87	38.62	63.80	98.3		
Medical teachers or mentors	developed	28	84,076	46.43	36.63	56.52	99.8	0.73	0.48
	developing	4	995	51.14	33.97	68.04	95.4		
	before 2010	21	49,654	48.48	36.93	60.19	99.8	0.70	0.54
	after 2010	11	35,417	43.87	27.94	61.18	99.7		
Career opportunities	developed	31	79,867	38.41	29.61	48.04	99.8	0.60	0.74
	developing	7	2,056	47.32	30.38	64.91	98.1		
	before 2010	20	43,417	47.97	33.54	62.74	99.8	0.24	1.68
	after 2010	18	38,506	32.38	21.68	45.31	99.5		
Workload or working hours	developed	15	20,970	42.14	31.35	53.72	98.6	0.34	1.39
	developing	5	1,081	25.72	13.29	43.88	95.3		
	before 2010	9	19,456	43.93	29.43	59.54	98.8	0.41	1.21
	after 2010	11	2,595	32.70	29.43	59.54	97.4		
Income	developed	39	107,091	34.01	26.89	41.93	99.8	0.84	0.29
	developing	11	2,700	37.11	27.06	48.41	96.4		
	before 2010	25	68,714	37.01	25.95	49.62	99.8	0.41	1.18
	after 2010	25	41,077	32.67	26.04	40.07	98.9		
Length of training	developed	15	41,246	33.95	28.72	39.60	98.4	0.31	1.48
	developing	3	800	22.92	10.94	41.85	94.0		
	before 2010	7	8,811	26.72	15.89	41.29	98.9	0.28	1.59
	after 2010	11	33,234	35.87	29.67	42.59	96.9		
Prestige	developed	17	27,987	23.96	19.20	29.47	97.3	0.01	4.71
	developing	9	2,642	47.65	34.41	61.24	97.6		
	before 2010	12	25,542	26.46	20.78	33.03	96.7	0.25	1.67
	after 2010	14	5,087	35.22	24.70	47.40	98.3		
Advice from others	developed	14	81,205	25.95	19.27	32.64	99.8	0.36	1.33
	developing	4	1,487	36.34	18.91	53.77	98.1		
	before 2010	10	48,319	22.93	17.85	28.01	99.5	0.31	1.47
	after 2010	8	34,373	33.65	25.12	42.18	99.1		
Student debt	before 2010	5	6,610	20.29	15.86	25.57	81.8	0.69	0.59
	after 2010	3	32,307	11.08	1.58	49.08	99.6		

Figure S1. Flow Diagram of the Study Inclusion.

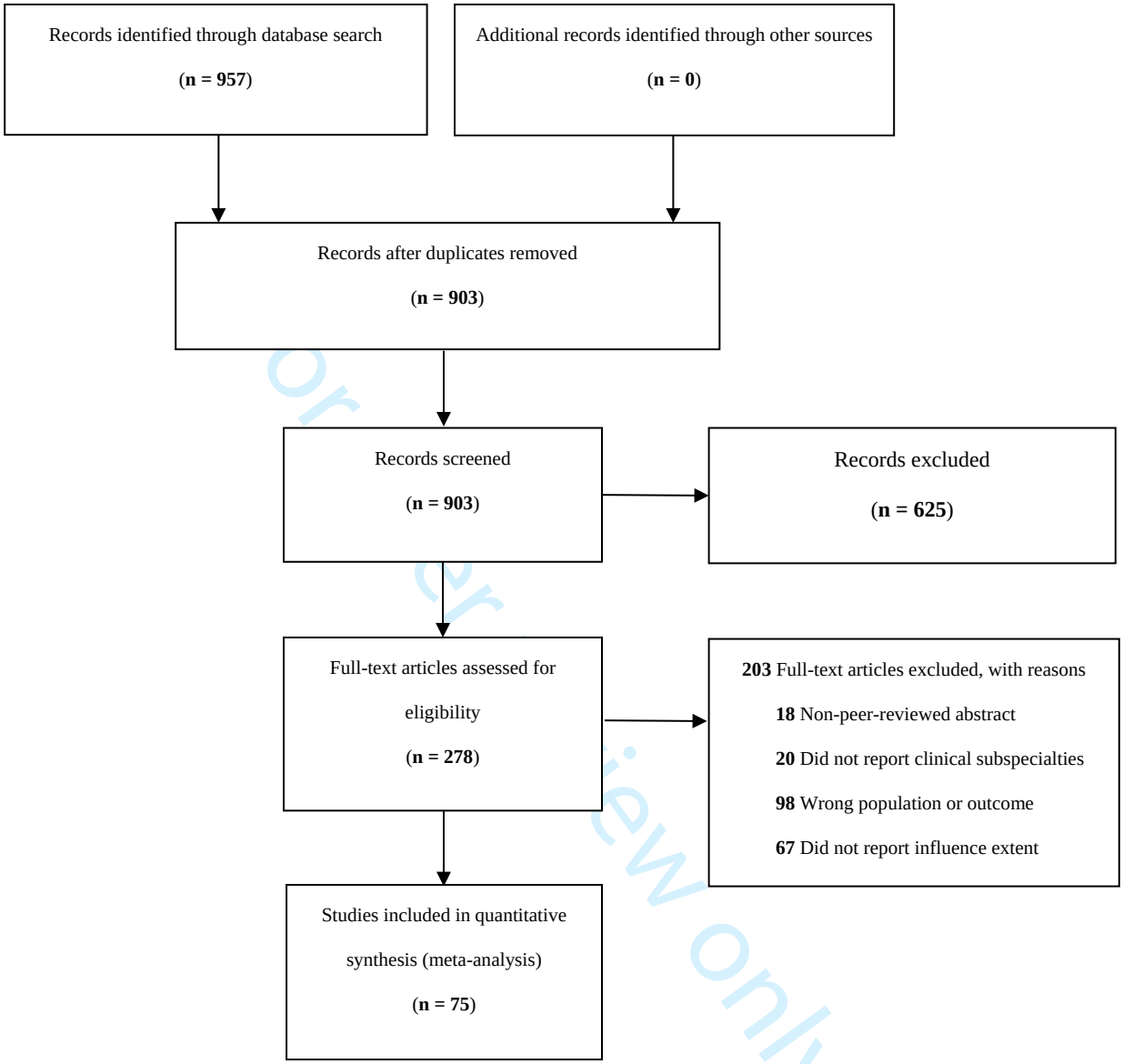


Figure S2. Forest Plot of "Academic Interest".

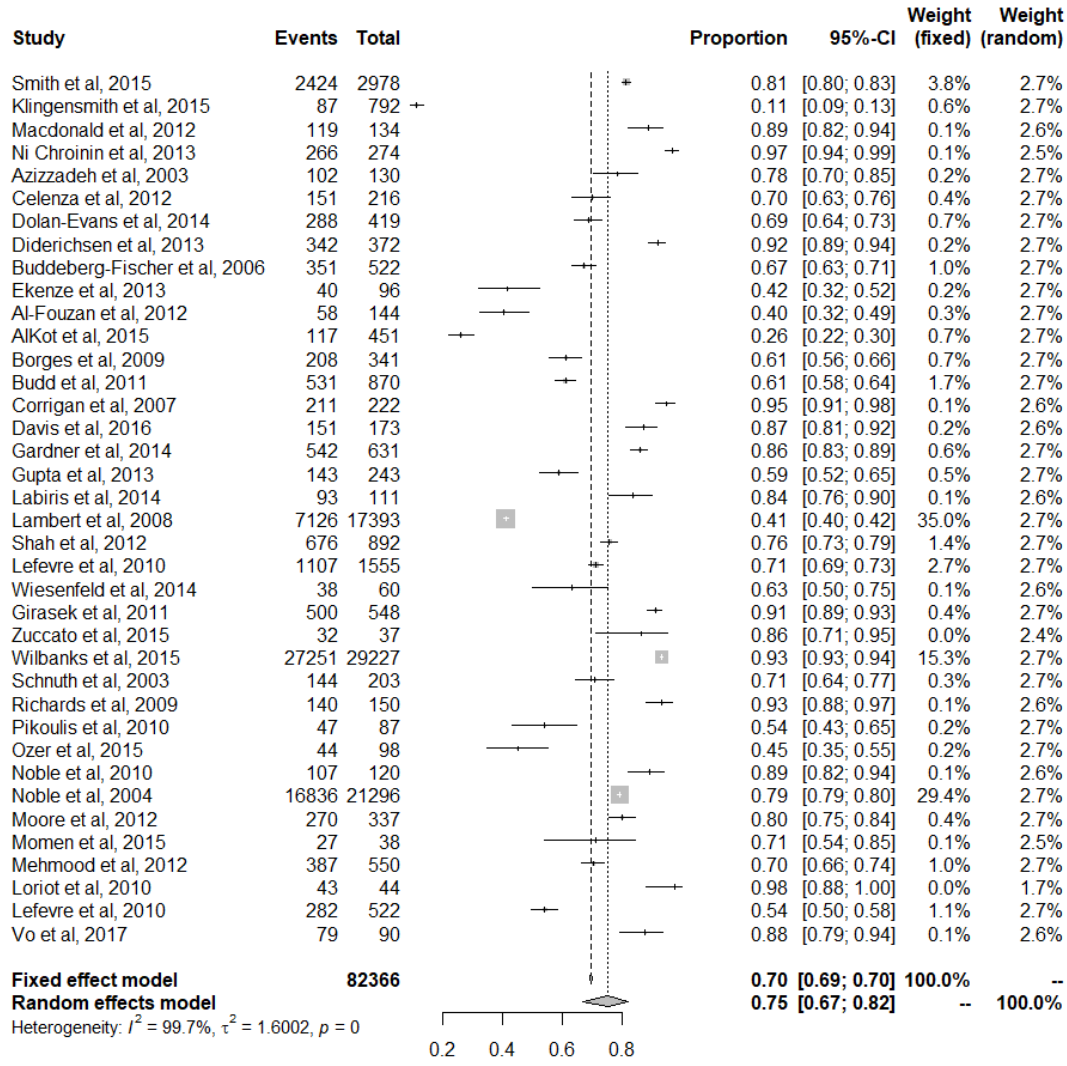


Figure S3. Forest Plot of "Competencies".

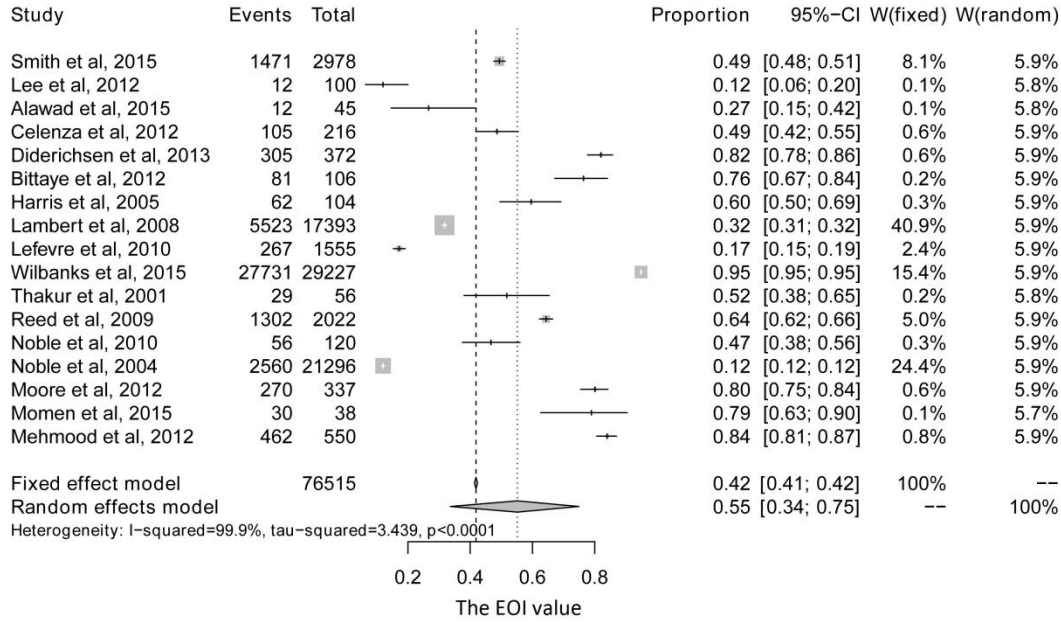


Figure S4. Forest Plot of "Controllable Lifestyle or Flexible Work Schedule".

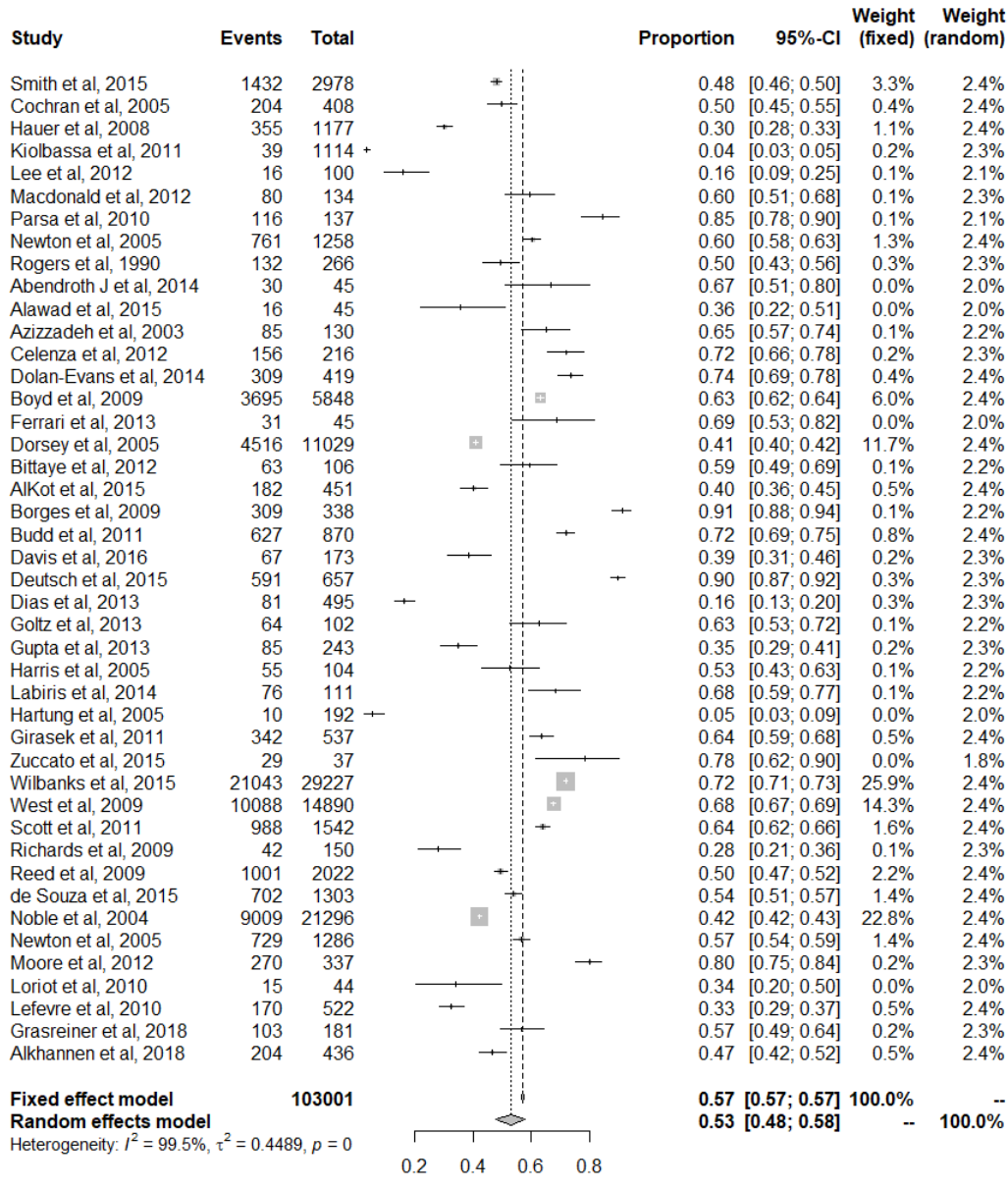


Figure S5. Forest Plot of "Patient Service Orientation".

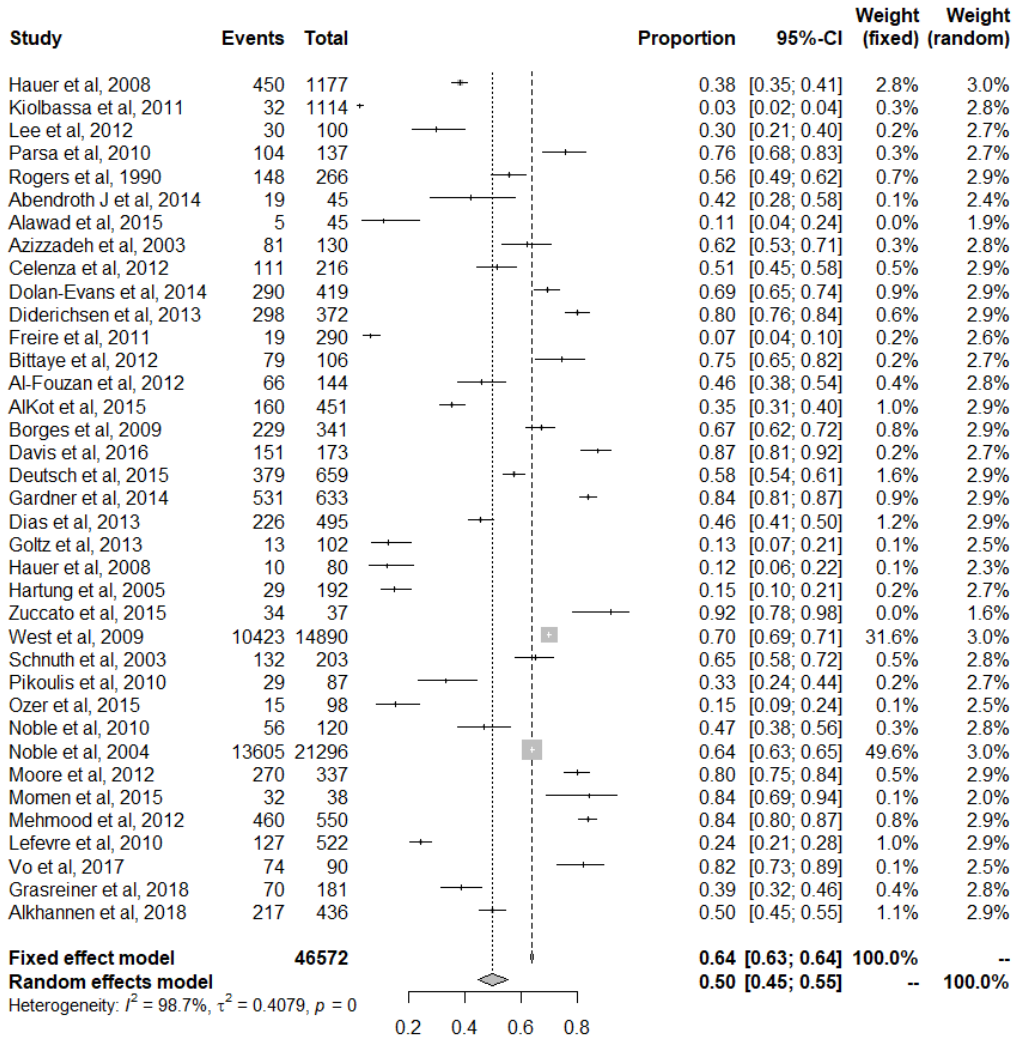


Figure S6. Forest Plot of "Medical Teachers or Mentors".

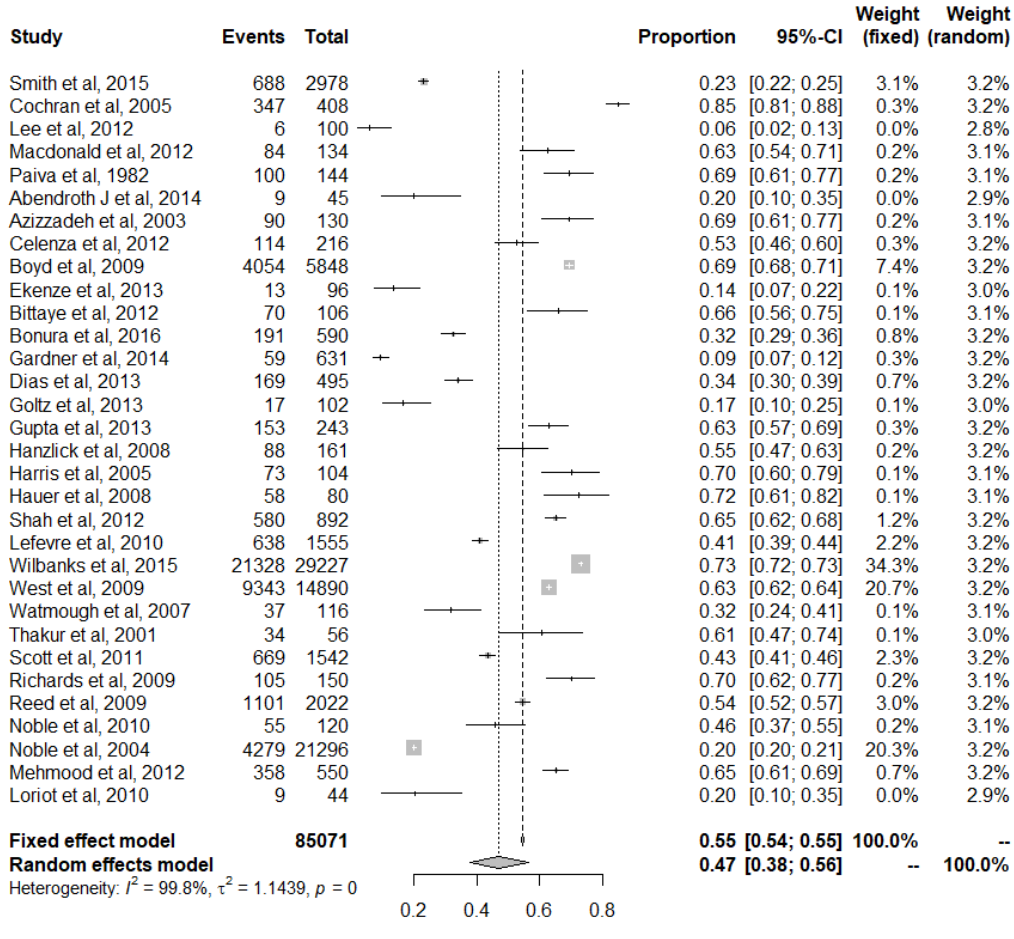


Figure S7. Forest Plot of "Career Opportunities".

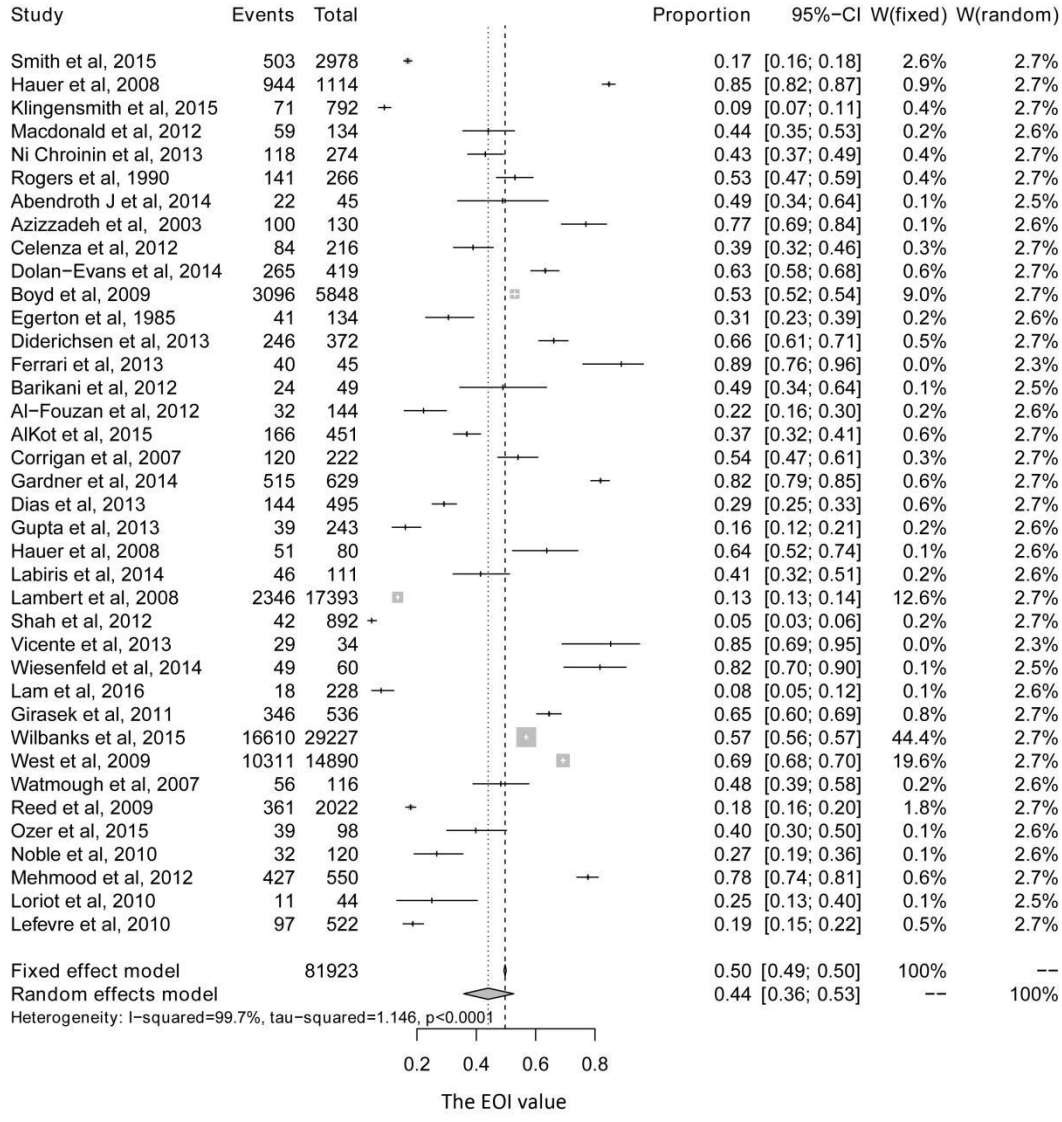


Figure S8. Forest Plot of "Workload or Working Hours".

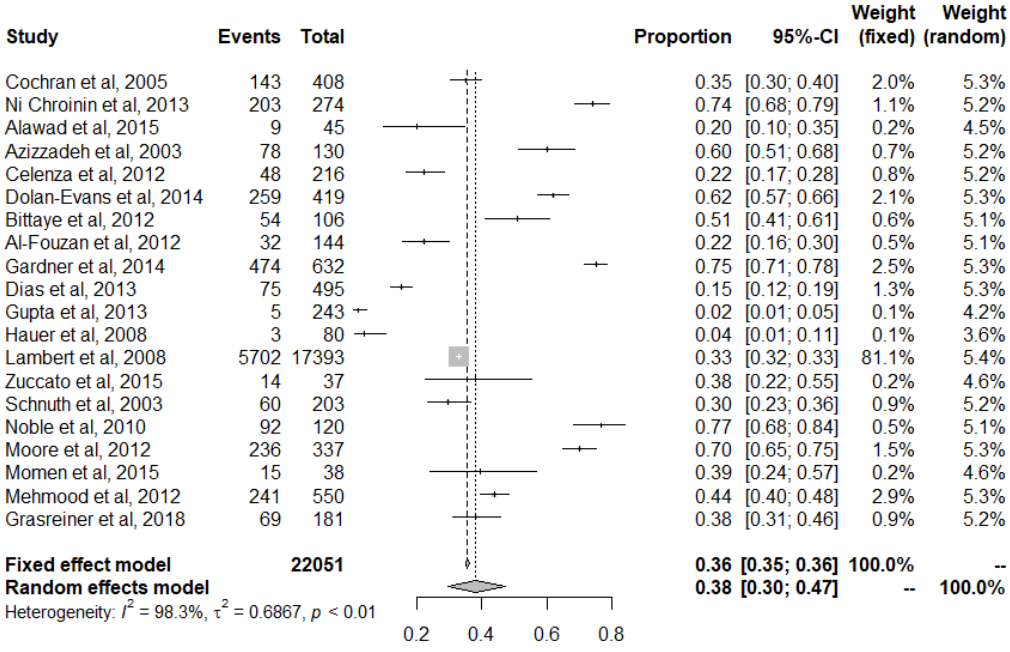


Figure S9. Forest Plot of "Income".

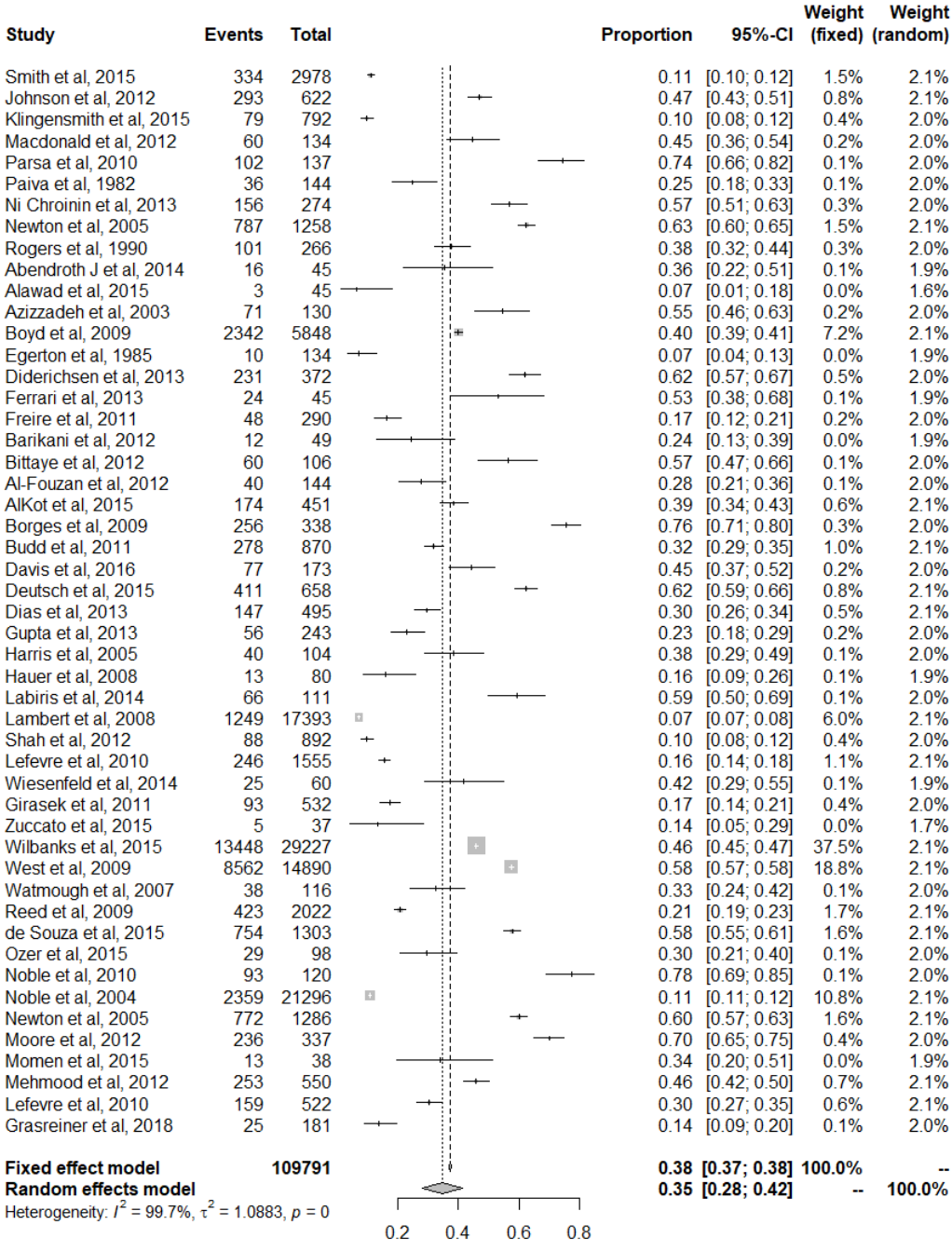


Figure S10. Forest Plot of "Length of Training".

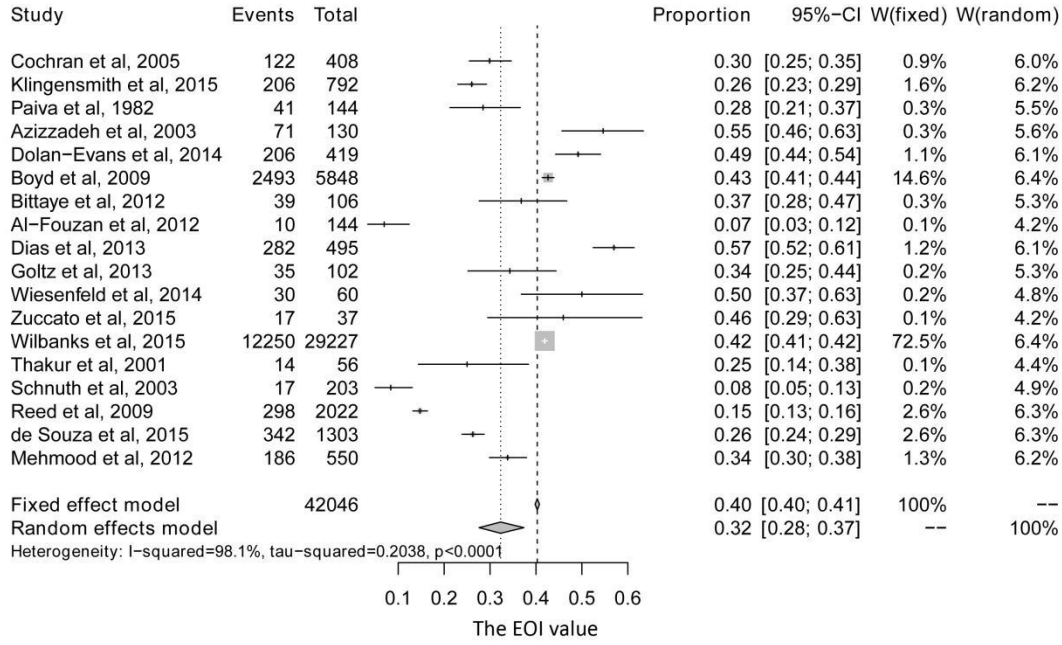


Figure S11. Forest Plot of "Prestige".

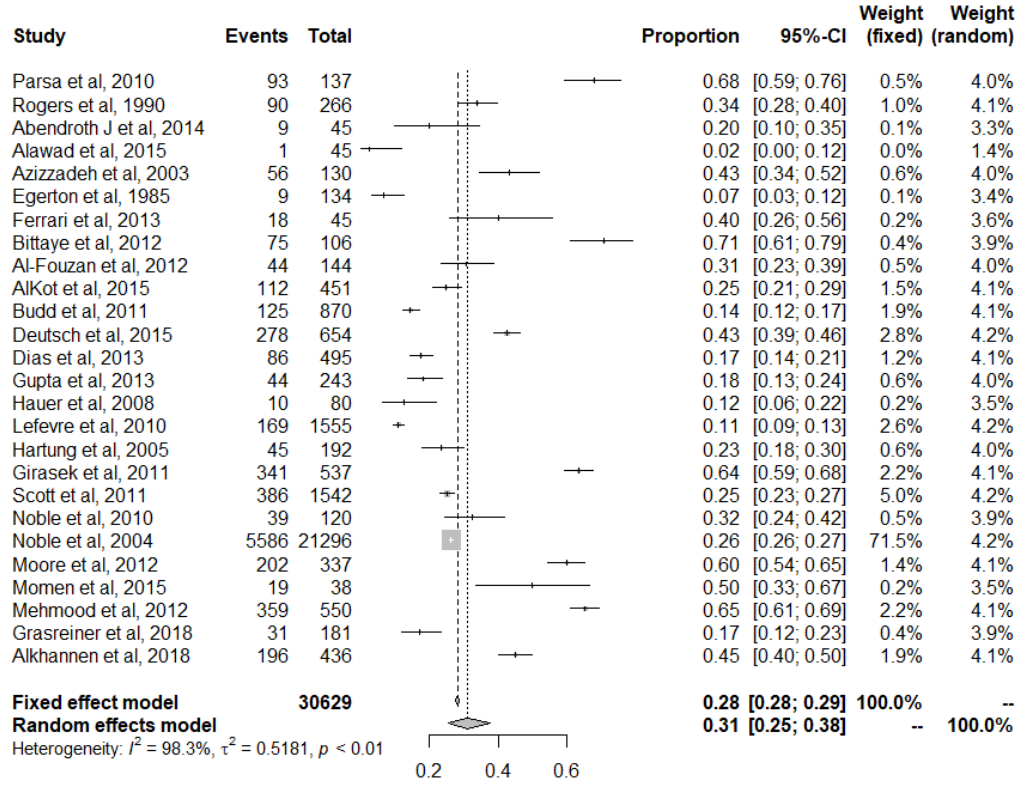


Figure S12. Forest Plot of "Advice from Others".

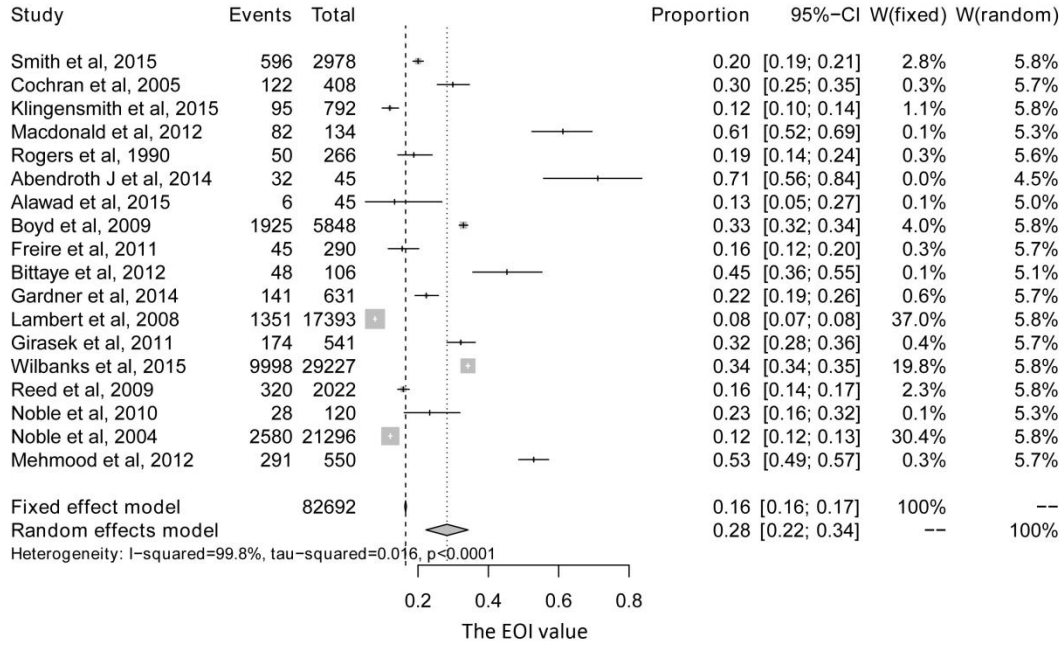


Figure S13. Forest Plot of "Student Debt".

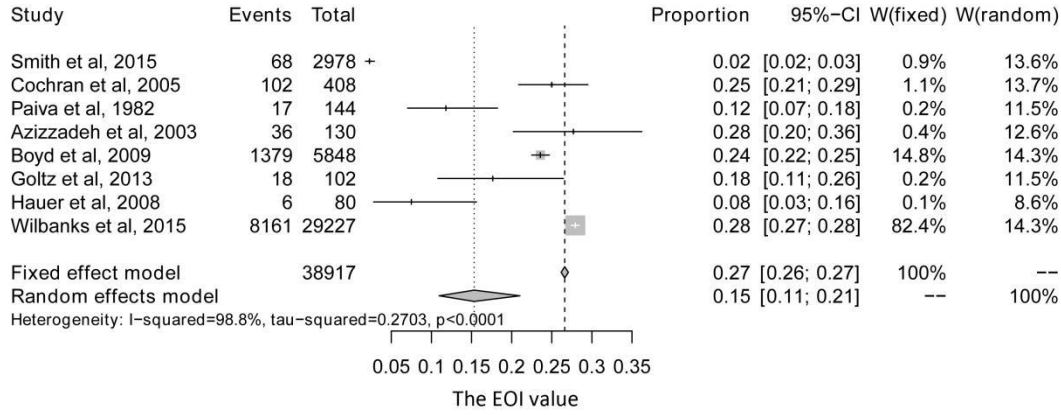
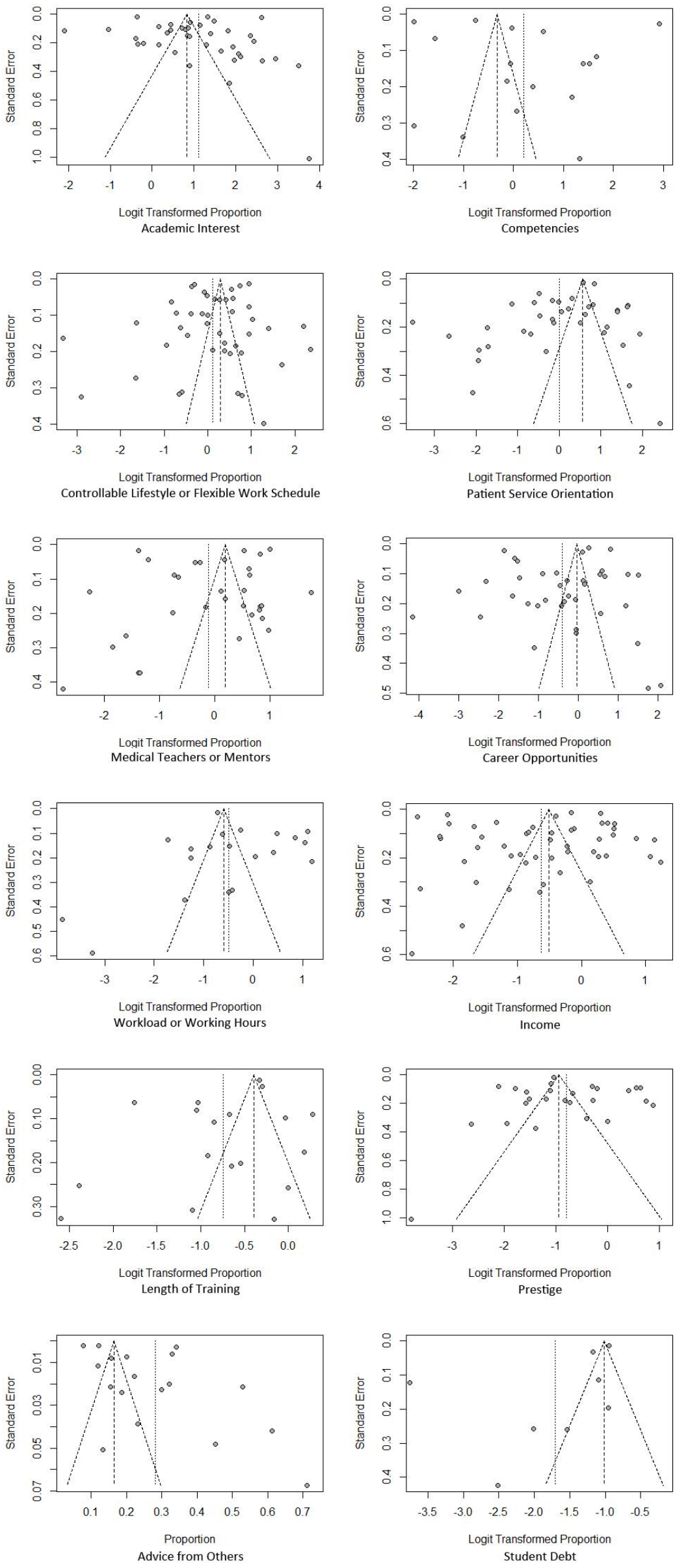


Figure S14. Funnel Plots of the Publication Bias Testing of the 12 Factors.



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5, 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7-8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	8
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

MOOSE Checklist for Meta-analyses of Observational Studies

Item No	Recommendation	Reported on Page No
Reporting of background should include		
1	Problem definition	5
2	Hypothesis statement	5
3	Description of study outcome(s)	5
4	Type of exposure or intervention used	5
5	Type of study designs used	5
6	Study population	5
Reporting of search strategy should include		
7	Qualifications of searchers (eg, librarians and investigators)	6
8	Search strategy, including time period included in the synthesis and key words	5
9	Effort to include all available studies, including contact with authors	5
10	Databases and registries searched	5
11	Search software used, name and version, including special features used (eg, explosion)	6
12	Use of hand searching (eg, reference lists of obtained articles)	5
13	List of citations located and those excluded, including justification	5-6
14	Method of addressing articles published in languages other than English	5
15	Method of handling abstracts and unpublished studies	5
16	Description of any contact with authors	5
Reporting of methods should include		
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	6
18	Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	6-7
19	Documentation of how data were classified and coded (eg, multiple raters, blinding and interrater reliability)	6-7
20	Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	6
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	6
22	Assessment of heterogeneity	6
23	Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	6-7
24	Provision of appropriate tables and graphics	5-7
Reporting of results should include		
25	Graphic summarizing individual study estimates and overall estimate	8
26	Table giving descriptive information for each study included	7
27	Results of sensitivity testing (eg, subgroup analysis)	8
28	Indication of statistical uncertainty of findings	7-9

Item No	Recommendation	Reported on Page No
Reporting of discussion should include		
29	Quantitative assessment of bias (eg, publication bias)	13
30	Justification for exclusion (eg, exclusion of non-English language citations)	13-14
31	Assessment of quality of included studies	13-14
Reporting of conclusions should include		
32	Consideration of alternative explanations for observed results	14
33	Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	14
34	Guidelines for future research	14
35	Disclosure of funding source	15

From: Stroup DF, Berlin JA, Morton SC, et al, for the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group. Meta-analysis of Observational Studies in Epidemiology. A Proposal for Reporting. *JAMA*. 2000;283(15):2008-2012. doi: 10.1001/jama.283.15.2008.

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