Review Article

Psychosocial aspects of colour vision deficiency: Implications for a career in medicine

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ABSTRACT

Colour vision deficiency (CVD) is a common problem and persons with CVD experience difficulties in daily life, early learning and development, education, choice of careers and work performance. Medical professionals with CVD also report difficulties in everyday tasks, training in medicine and performance of medical duties. However, because of limited evidence, the real impact of CVD on the lives of medical professionals is unclear, especially regarding the practice of medicine by doctors. The nature and severity of CVD, awareness of its impact, personal circumstances and the ability to cope with the deficiency are the major factors that determine the impact of CVD. However, there is a paucity of methodologically sound research on social and psychological aspects of CVD. Currently, early detection, enhancing awareness and offering support are the only proven ways of helping medical professionals with CVD. With the growing emphasis on equality and inclusivity of those with deficiencies, it is desirable to strike a balance between concerns about patient care and the rights of medical professionals with CVD to pursue their careers. Therefore, any future research also needs to focus on psychological aspects of CVD while exploring its impact on a career in medicine.

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INTRODUCTION

The impact of colour vision deficiency (CVD) on those intending to pursue a career in medicine has been in the news following the recommendation of a committee appointed by the Supreme Court to remove CVD-related restrictions at all stages of medical education and training.[1] CVD, often wrongly referred to as colour blindness, is a common problem among people including medical professionals. Individuals with CVD experience difficulties in everyday tasks, education and in their careers. However, because of limited evidence, the real impact of CVD on the lives of these people is unclear. The impact of CVD on medical practice is also equally unsettled. Moreover, with the growing emphasis on equal opportunity, it is necessary to strike a balance between concerns about patient care and the rights of doctors with CVD—a principle emphasized by the judgment of the Supreme Court.

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CVD AMONG THE GENERAL POPULATION

Prevalence and severity

Although a comprehensive review of the aetiology, prevalence and clinical aspects of CVD is beyond the scope of this paper, several important points can be extracted from some reviews on the subject.[2–5]

Red-green CVD is the most common variety of congenital CVD. It consists of milder or anomalous trichromatic forms (protanomaly or red weakness and deuteranomaly or green weakness) or more severe or dichromatic forms (protanopia and deuteranopia). Other rarer defects include blue-yellow weakness (tritanopia and tritanomaly) and achromatopsia or the complete absence of colour vision. CVD is one of the most common disorders of vision and its congenital form affects about 8% of men and 0.4% of women with North-European ancestry. The gender difference in prevalence results from the red-green type being inherited in an X-linked recessive manner. The influence of a genetic aetiology also makes for varying prevalence rates among different ethnic populations, with rates being lower among Asians, Africans and South Americans. In keeping with this trend, studies from India have found prevalence rates of 2%–4% on average although rates have varied from 1% to 8% across studies.[6–10]

The extant literature also suggests that total 'colour blindness' is extremely rare. Rather, difficulties with colour vision range on a continuum from mild to severe levels of deficiency. When examined for severity, approximately equal numbers of people with red-green forms of CVD are graded as having mild, moderate or severe deficiency.[11] In addition, prevalence studies suggest that only about a quarter of the individuals have a severe form of CVD; the remaining three-quarters may either have normal or near-normal colour vision, or more commonly have a level of ability intermediate between normal colour vision and defective colour vision approaching severe CVD.[2–4,12]

Difficulties associated with CVD

CVD affects many areas of life, and its adverse impact is experienced at all stages, i.e. from childhood to adolescence and adulthood.[2–5,13,14] Adverse effects of CVD have been reported mainly in areas of daily living, early learning and development, subsequent educational and occupational performance and other areas such as health-related activities (Table I).

Daily living

The principal tasks where colour is used to organize our daily life are classified into three or four categories.[11,13] Comparative colour tasks are those which require matching or differentiating colours,

Table I. Difficulties associated with colour vision deficiency (CVD)

Study details	Results	Remarks
	Daily life	
Steward and Cole (1989)[15] Questionnaire-based study; 102 with CVD and 102 controls	Problems with colours of everyday objects, e.g. clothes, accessories and furniture; with arts, crafts and hobbies; problems in recognizing freshness of food; in sports; in leisure activities, e.g. watching TV; in health-related activities, e.g. detecting skin rashes or taking medicines	Number of problems experienced was roughly related to severity of CVD
Tagarelli *et al*. (2004)[16] Questionnaire-based study; 151 with CVD and 302 controls	Statistically significant differences between the CVD and the control group in choosing clothing and outfits; in distinguishing natural colours and colours at work or hobbies; in recognizing freshness of food; difficulties in watching TV or sports; in identification of skin lesions	About 40% with CVD had difficulties in contrast to the 93% found by Steward and Cole[15]
Spalding (1997)[17] Questionnaire-based study of 40 doctors with CVD	Up to 70% with CVD had problems with dress sense and décor; with other objects, e.g. birds, fruits and books; with sports; with artistic sense and hobbies; with maps, food and drink; with naming, memory and recognition of colours; and had difficulties in practice of medicine	For medical practice, severity of CVD was associated with the number of difficulties reported
	Driving	
Questionnaire-based studies	Steward and Cole[15]—30% with CVD had difficulty in distinguishing traffic signals, in recognizing road traffic signs (38%–50% with severe CVD and 12%–20% with mild CVD); 15% have difficulty in seeing brake lights of cars and 7%–8% in viewing red-warning lights	Difficulties with traffic signals increased with severity of CVD
	Tagarelli *et al*.[16]—regular use of car and preference for day-time driving was significantly more common among those with CVD *v.* controls; no significant differences in distinguishing traffic signals, road accidents, night-time driving, having a licence, or years of driving	Driving difficulties uncommon in contrast to Steward and Cole[15]
	Spalding[17]—about 33% had difficulties with traffic lights and signals	Small sample of only doctors
Experimental studies (laboratory-simulation and field-trial studies)	Experimental studies show that people with CVD have difficulties in recognizing colours of traffic signals, have slower response times to traffic signals, require shorter distance to understand signals and are at a higher risk for rear-end collisions[3,13,18–21]	Driving difficulties are more common in those with severe CVD. Those with mild CVD are able to compensate for their difficulties adequately.
Population-level studies	Cumberland *et al*. (2004)[22] did not find an increased rate of road injuries in those with CVD	
Accident data	Majority of the studies do not find over-representation of drivers with CVD among those involved in accidents[3,13,18–21,23–26]	
	Schooling	
Case–control studies	No differences between children with CVD and children with normal colour vision on intelligence and reading achievement in certain studies[27–29]	Children with CVD have difficulties in several subjects, but studies on impact of CVD on academic achievement have had conflicting results.
	Grassivaro Gallo *et al*.[33,34] showed significantly lower general academic scores among children with CVD (n=82) compared to children with normal colour vision (n=82) in two cross-sectional studies	Nevertheless, the weight of evidence indicates no significant association between CVD and educational outcomes.[3,21,30–32]
	Suero *et al*.[35] found poorer performance in certain tasks but not in others among children with CVD (n=39) *v.* children with normal colour vision	
	Ugalahi *et al*.[36] found difficulties with colour-related school work among children with CVD (n=37) *v.* children with normal colour vision	
Questionnaire-based studies in adults	Tagarelli *et al*.[16] found no significant differences in the disciplines studied between CVD and the control group	
Population-level studies	Grassivaro Gallo *et al*.[37] found that children with CVD (n=831) reported more colour confusion, learning difficulties, poorer learning skills and lesser satisfaction with schooling than children with normal colour vision (n=34 309)	
	Cumberland *et al*.[22] found that CVD was not associated with mathematics and reading scores among children and highest educational qualification attained later (n=499)	
	Career choice and difficulties at work	
Experimental studies	Experimental studies show that people with CVD perform poorly on occupation-specific tasks[3,13,21,23,38]	People with CVD perform poorly on occupation-specific tasks. Impaired performance is associated with increasing severity of CVD. Impact of deficient

(continued)

Table I. Difficulties associated with colour vision deficiency (CVD) *(continued)*

Study details	Results	Remarks
		performance is limited in real-world settings, because people with CVD compensate successfully for their difficulties. Norms for colour vision standards are being relaxed.
Questionnaire-based studies	A number of early studies found that CVD did not influence choice of careers and was not associated with occupational difficulties[3,21,39,40]	
	Steward and Cole[15]—30% reported that their CVD had affected their choice of career; 25% reported that they had been excluded from an occupation because of their CVD; 25% reported difficulties with colour at work	
	Tagarelli *et al*.[16]—People with CVD had little difficulty in maintaining permanent employment though they were more likely to hold subordinate than independent jobs	
Population-level studies	Cumberland *et al*.[41] found no significant differences between people with CVD *v.* normal controls in employment in major occupational groups, employment status, employment history and unintentional injuries. Men with CVD were under-represented in certain occupations, e.g. transport operations, aircraft and ship officers, electrical and electronic engineering, fibre and textile industry, arts, sculpture and design	
	Health-related activities	
—	People with CVD have difficulties with self-care-related medical procedures[3,11,13,21]	Few studies

for example in painting or decorating a house, or in textile, paint and plastics industries. Connotative colour tasks are those in which colours are assigned specific meanings that determine the significance of the task. Recognizing traffic signals and other colour-coded information in electrical appliances, chemical tests and colours of eatables are some examples of such tasks. In denotative tasks, colour is used to identify objects or discern complex visual information. These tasks include visual scanning and search to distinguish coloured objects from their background. Aesthetic colour tasks involve the symbolic use of colour to convey ideas or emotions by artists and designers. Since these different uses of colour are common in our daily life, it is not surprising that people with CVD experience problems in daily living. Questionnaire-based studies have shown that a number of people with CVD have problems in negotiating everyday tasks such as driving, cooking, decorating, dressing and sports or leisure activities (Table I).[15–17] However, the proportion of people with difficulties varies from around 40% to 93% in these studies. One factor accounting for this wide range could be the varying severity of CVD.

Driving

Safe driving requires proper recognition of traffic signals, road signs and colour-coded lights. Laboratory-simulation and field trials have shown that drivers with CVD have difficulties in recognizing coloured traffic signals, have slower response times to these signals, require shorter distance to understand signals, have reduced sensitivity to red lights and are at a higher risk for rear-end collisions.[3,13,18–21] The three questionnaire-based studies have come to somewhat different conclusions about driving difficulties of people with CVD.[15–17] Two of them found that about one-third of the drivers with CVD had various difficulties with traffic signals and other colour signals on the road,[15,17] while the third study found no significant differences in distinguishing traffic signals and few differences in other aspects of driving between drivers with and without CVD.[16] Severity of CVD is a confounding factor since driving difficulties are more common in those with severe CVD.[15,21] Moreover, drivers can be helped by having to view traffic signals from much shorter distances than maritime, aviation and rail signals. Other environmental cues such as positioning of traffic lights, their relative brightness and movement of other traffic can also help. Specially designed traffic lights and eyeglasses can be of use in certain instances. Finally, those with CVD can compensate for their colour vision deficits by adopting safer and more cautious driving practices.[3,13,18–21] The lack of impact of CVD on driving in natural conditions is endorsed by population-level studies and accident data.[3,13,18–26] More than a dozen studies have examined accident rates among drivers with CVD, with the majority finding no differences between those with or without CVD. Therefore, though CVD is a potential risk factor for driving because of errors in colour-dependent driving tasks, the weight of the evidence indicates that CVD is not associated with unsafe driving.

Schooling and education

Congenital CVD is a hidden disability because, though present from birth, its effects become manifest only when children begin to attend play-schools or regular schools. Since learning from an early age is heavily dependent on colour vision and because CVD is generally not recognized early, it often leads to considerable difficulties in learning. Children with CVD are often labelled as slow learners, which could have adverse psychological impact on them, or could elicit negative reactions from teachers and parents. Young children with CVD have problems in learning, in playing and in the area of personal safety, while older children lag behind in many subjects, especially science subjects.[3,21] However, the impact of CVD on academic performance remains uncertain because of conflicting findings. While certain cross-sectional controlled studies with relatively smaller samples have found that intelligence and reading ability did not differ between children with CVD and those with normal colour vision, other studies have found school work and academic achievement to be poorer among those with CVD.[16,27–33] One large cross-sectional study did find more colour confusion, learning difficulties, poorer learning

skills and lesser satisfaction with schooling among children with CVD compared to controls,[37] but another better-designed longitudinal cohort study found that CVD was not associated with mathematics and reading scores among children and the highest educational qualification attained by them at a later age.[22] Therefore, most reviewers have concluded that there is no clear association between CVD and educational outcomes.[3,21,30] Consequently, there have been calls for abandoning screening at the school-level, and colour vision testing has been largely phased out at school-entry in countries such as the UK.[21,22,32]

Choice of careers and workplace difficulties

People with CVD have been conventionally debarred from certain occupations because of reasons of safety or lack of quality assurance.[2,3,21] Occupations requiring normal colour vision to ensure safety include transport, defence and the electronic industries. Occupations requiring surface colours to be recognized or aesthetic judgements about colours to be made, e.g. textile and chemical industries, designing or interior decoration, also exclude those with more severe forms of CVD because of limitations in quality assurance. CVD might create difficulties in other occupations such as teaching, art and medicine, but people with CVD are not usually barred from these fields. Notwithstanding such restrictions, the evidence linking CVD with career choice and workplace difficulties is not clear. Experimental studies show that people with CVD, particularly those with more severe forms, perform poorly on occupation-specific tasks.[3,13,21,23,38,39] However, the results of questionnaire-based studies are equivocal with some showing CVD to be a determining influence and others failing to do so.[15,16,40] Moreover, a population-level cohort study found no significant differences between people with or without CVD in employment type, employment status, employment history and risk of workplace injuries.[22,41] The lack of evidence clearly linking CVD with occupational difficulties and growing awareness of equal opportunity legislation has meant that many occupations have relaxed their requirements regarding colour vision standards.[2,13,21,38]

Confounding factors

A consistent theme in literature on different difficulties associated with CVD is the discrepancy between the problems linked to CVD found in experimental situations and performance in real-world settings. It is a common finding that laboratory simulations and field trials often do not reflect performance in more natural settings.[13,22,41,42] This is because a number of factors such as existing circumstances, environment, memory and expectation play a role in determining the eventual association between CVD and the difficulties reported in real-life situations. Severity of CVD is another major confounder because it appears to be uniformly associated with the extent of disability in different domains.[13,21,22,38,40,41] Lack of awareness and denial is also likely to lead to under-reporting of problems and minimization of their seriousness.[12] Finally, people with CVD develop a number of adaptive strategies, consciously or unconsciously, to compensate for their deficiencies. They learn to use other properties of objects such as hue, saturation and brightness or spatial orientation and other environmental clues to successfully overcome their problems.[13,22,32,41] Thus, the results of experimental studies are often not replicated at the population level.[22,41]

Psychological aspects of CVD

The first description of CVD in 1794 by John Dalton contained a detailed description of its subjective aspects.[13] However, the existing literature on CVD appears to have largely ignored the subjective and psychological aspects of the disability. Since CVD is present from birth, it may hamper early learning and development. Although the findings on school performance are equivocal (Table I), the difficulties some children face in school can seriously undermine their confidence and cause frustration and anger.[3,32,43,44] In addition, in young children, the presence of CVD may create difficulties in other areas such as playing, eating or personal safety. These problems are made worse in many instances where the CVD remains undetected for long. Adverse experiences such as these have the potential to affect the child's self-esteem and more severe problems can even lead to social withdrawal or refusal to go to school. Moreover, trauma resulting from childhood visual impairment can affect self-concept and self-integration at a later age.[45] Thus, adults who have experienced lifelong visual confusion because of CVD may continue to display a range of negative psychological reactions such as frustration, shame and lack of confidence. Grassivaro Gallo *et al*.[37] have proposed that persons with CVD have difficulty reconciling their own perceptions of reality with those of others. Unawareness of CVD leads them to the conclusion that they are defective and need to change. However, failed attempts at adapting to prevalent norms often result in a sense of lack of control, which in turn leads to helplessness, demoralization, apathy, withdrawal or even rebellion. Impaired self-efficacy and self-esteem are the eventual outcomes of chronic and persistent feelings of helplessness and discouragement. Despite these potential psychological sequelae of CVD, the evidence linking CVD with poor self-esteem or other maladaptive personality traits is meagre and often inconsistent, with psychological difficulties being found only in a few studies (Table II).

One consistent finding across many studies has been the lack of awareness about the presence and severity of CVD among its sufferers. About one-fifth to one-third of those with CVD do not know about their condition.[5] Steward and Cole[15] found that 25% of those with milder forms of CVD (trichromats) and even 5% with more severe forms (dichromats) were unaware about their CVD. Many people become aware of their CVD only during their school-years. However, despite having their vision checked, 50%–90% of primary schoolchildren remain unaware.[15,32,54,55] Awareness improves during secondary schooling, especially among those with more severe CVD; still, 40%–80% leave school without being aware of their CVD. Awareness among others such as teachers or family members is also low.[7,32,37] Unawareness is partly due to the fact that people with CVD might have not been properly tested and informed about their condition. Moreover, they learn to hide their difficulties by adapting to their deficiency using a variety of cues and assumptions to guess the colour of the object they are seeing. Finally, an element of denial is also present (Table II). This often arises from an internal struggle among people with CVD whether to reveal their problems or to hide them to avoid facing discrimination.[11,12]

CVD AND THE MEDICAL PROFESSION

Prevalence and severity

The prevalence of CVD among medical workers suggests that those in the medical profession are not immune to problems arising from CVD. The rates of CVD among medical professionals have differed across studies possibly due to methodological discrepancies (Table III).[11,12,57,58,70] Although rates either lower or higher than that among the general population have been reported,

TABLE II. Psychological aspects of colour vision deficiency (CVD)

Study details	Results
Lakowski (1970)[46#] 106 printers' apprentices with a mean age of 15 years assessed with the High School Personality Questionnaire	Personality traits such as anxiety, neuroticism, introversion, extraversion, shyness, restraint, lack of conscientiousness and emotional instability associated with CVD
Bradley (1970)[47] Psychoanalysis of 3 patients with CVD	CVD exacerbates a sense of uncertainty, a tendency to doubt and insecurity in relations with others
Pickford and Cobb (1974)[48] * 219 men and 35 women with CVD assessed for attitudes to CVD	11% (*n*=28) had abnormal attitudes including 16 with denial and 12 with either exhibitionism, intellectualism, overcompensation or anxiety; 3% (*n*=8) trying to cope with their CVD
Pickford and Cobb (1974)[48 #] 19 subjects with CVD administered the Eysenck Personality Inventory	Subjects with CVD had high extraversion, low introversion and low neuroticism
Cobb (1980)[49] 7 children with CVD with 7 matched controls	Children with CVD had poorer reading ability but no abnormal attitudes or emotional disturbances
Cobb (1980)[49] 11 children with CVD with 11 matched controls assessed with the Eysenck Personality Inventory	No difference on school performance or on the Eysenck Personality Inventory scores
Steward and Cole (1989)[15] Reaction to being told about CVD among 18 subjects who were previously unaware of it	9 expressed disbelief suggestive of denial while the other 9 were surprised but accepted they had problems indicating readiness to cope
Benjamin et al. (1993)[50] 17 men with CVD; 9 concordant (brother with CVD) and 8 discordant pairs assessed with the 16 Personality Factor test	Self-sufficiency was found to be lower among sibling pairs concordant for CVD than sibling pairs discordant for CVD
Perez-Carpinell et al. (1995)[51] 312 secondary school students 14–16 years of age assessed with the 16 Personality Factor test	16 subjects with CVD had some maladaptive traits but the influence of CVD on personality was minimal (CVD contributed to <20% variance in traits)
Coren and Harland (1995)[52] 1014 undergraduate university students assessed with the Eysenck Personality Inventory	Persons with poor colour discrimination scored significantly higher on neuroticism but not extraversion
Coren and Harland (1995)[52] 1148 undergraduate university students assessed with the NEO Five-Factor Inventory	Persons with poor colour discrimination scored significantly higher on both neuroticism and extraversion
Larsson and von Stumm (2015)[53] 200 adults examined for IQ and colour vision deficits	No association between colour vision and intelligence scores or self-perceived performance adjusting for IQ

* Attitudes to CVD included denial–disagreement with test results and unwillingness to accept any problems due to CVD; exhibitionism—readily displaying the defect; intellectualism—arguing about what the tests prove; overcompensation—belief that CVD will enrich the subject's life; anxiety—infrequent as an overt attitude, but present as a part of all attitudes; coping—noticeable efforts to adjust to the defect # Extraversion is characterized by being outgoing, talkative, high on positive emotions and need for external stimulation; introversion is the opposite of extraversion; neuroticism is characterized by unstable emotions, poor coping and high levels of depression and anxiety.
IQ intelligence quotient

CVD is as common among medical professionals as in other people. Studies on medical students from the Indian subcontinent also show that rates range from 1% to 6%, which is similar to the rates among the general population.

Difficulties associated with CVD

The problems that students and doctors with CVD face while training in and practising medicine have been noted for more than 100 years.[71,72] However, possibly because of reluctance of the medical profession to acknowledge these problems, research on this aspect of CVD began in earnest only in the 1990s. Consequently, the evidence is not as extensive or methodologically sound as studies done among the general population. The bulk of evidence consists of studies using colour-dependent material for assessing medical skills of students or doctors in artificial test conditions. This is supplemented by a few questionnaire-based studies, direct observations of doctors while performing medical procedures and subjective accounts of their difficulties due to CVD (Table IV).

Despite the limited number of studies on the issue, certain conclusions about the difficulties faced by students, doctors and other medical workers with CVD can be drawn. First, there is reasonable evidence that a certain proportion of medical professionals with CVD face considerable difficulty in training and while carrying out their duties. A consistent finding is that the severity of CVD is associated with the level of performance across most of the studies that have examined severity. Accordingly, subjects with mild-to-moderate CVD often do not report facing any difficulties at all. In contrast, those with severe CVD not only experience considerable difficulties in their work but are also at greater risk of committing diagnostic and treatment errors, some of which may have potentially serious consequences. This affects the confidence of persons with CVD and diminishes their performance of medical duties. However, even the evidence for these observations is often variable and inconsistent. Almost all studies have small sample size and in some instances consist of self-selected doctors with mostly severe CVD.[17,77,78,80,81] Therefore, none of these findings can be considered conclusive unless larger and more representative samples are examined. The relative lack of naturalistic studies in actual clinical conditions creates further problems in interpreting the results of these studies. First test conditions differ from real-world conditions in many ways such

TABLE III. Prevalence of colour vision deficiency (CVD) among medical students

Study details*	Prevalence of CVD (%)	Remarks
	Reviews	
Spalding (1999)[11] Review of 13 studies	Medical students 5.5%–13%; doctors 7%–14%; technicians 2%–9%	Lower figures in certain studies attributed to self-selection. Variability in rates due to methodological differences across studies
Ali (2012)[56] Review of 5 studies	Medical students 8%–13%; doctors 11%; technicians 2%–9%	
Goh et al. (2014)[57] Review of 5 studies	Doctors 7%–13%; technicians 2%–9%	
	Medical students of the Indian subcontinent*	
Balasundaram and Reddy (2006)[58] 1427 healthcare personnel from Malaysia, 658 medical students (men 290 and women 368), 84 doctors (34 men and 50 women) and 769 others	Overall 3.2% Medical students—men 5.2%; women 0.3% Doctors—men 2.9%; women 0	Nurses (all women) 0.3% Medical assistants (all men) 8.2%
Pramanik et al. (2010)[59] 120 undergraduate medical students from Nepal	5.8% had CVD	–
Siddiqui et al. (2010)[60] 926 undergraduate medical and dental students including 410 men and 516 women from Pakistan compared with 7288 non-medical students	Overall 2.05% Men 4.4% Women 0.2%	Prevalence in men not significantly different from non-medical undergraduate students
Pramanik et al. (2012)[61] 215 medical and dental students from Nepal	5.6% had CVD	–
Mughal et al. (2013)[62] 2000 undergraduate medical students including 750 men and 1250 women from Pakistan	Overall 3.7% Men 2.4% Women 4.5%	Significantly higher prevalence in women not explicable
Agarwal et al. (2015)[63] 600 medical students including 287 men and 313 women from India	Overall 3% Men 4.5% Women 1.6%	17% had minor problems with studies, none had major difficulties
Patel et al. (2015)[64] 500 medical students including 185 men and 315 women from India	1.8% on Ishihara plates (men 1.6%, women 0.2%) 15% on FM 100 hue test (men 11.8%, women 3.2%)	88% had mild CVD, 3% had moderate and 9% severe CVD on the FM 100 hue test
Subha et al. (2015)[65] 568 undergraduate medical students including 287 men and 281 women from India	1.9% in men; none among women; none with severe defects	Only 1 of the 11 students aware of problem
Saha and Saha (2016)[66] 300 1st year medical students including 168 men and 132 women from India	4.8% in men; none among women	–
Lashari et al. (2016)[67] 823 undergraduate medical students including 337 men and 486 women from Pakistan	Overall 0.7% Men 1.7% Women 0	–
Dhingra et al. (2017)[68] 1022 graduate and postgraduate medical students from India	3.4% in men; none among women	80% diagnosed for the first time on admission to the medical course
Khalid et al. (2017)[69] 240 dental students including 95 men and 145 women from Pakistan	Overall 3.8% Men 2.9% Women 0.8%	–

*All studies conducted using the Ishihara charts/plates except Patel *et al*. (2015) FM Farnsworth–Mansell

as illumination, speed and time pressure or working alone and during home visits, all of which cannot be replicated in test conditions. Second, doctors with significant deficits due to CVD often use other methods such as more intensive observation or examination, cross-checking, greater efforts to obtain information from other sources and seeking help from others colleagues to overcome their difficulties. They also tend to use additional cues from history and examination to compensate for the handicaps resulting from CVD. Finally, clinical decision-making is a complex process and none of these studies provide evidence for a causal

relationship between the difficulties reported due to CVD and patient management. Although doctors with CVD might commit errors in recognizing colour-dependent signs or findings, the extent and seriousness of these errors are not clearly evident from the existing studies. Medical errors are not uncommon and can result both from personal reasons as well as flaws in the system. It is likely that most of these errors due to CVD can be prevented by anticipating them and instituting preventative measures. It has been suggested that the risk of committing errors is minimized if circumstances are optimal (e.g. good illumination, use of aids, teamwork), when rapidity and time demands are not involved (e.g. in emergency settings) and where decision-making does not involve a single pivotal colour-dependent observation (e.g. severe bleeding).[11,56,57,70,92]

Awareness of CVD

Much like other people, many doctors are unaware of the severity of their CVD and assume their disability to be of little consequence.[17,70] Two of the three histopathologists in the study by Rigby *et al*.[75] were unaware of their deficiency, while Spalding[17] found that 19 of their 24 general practitioners with severe CVD did not know about their problems, while many became aware about the extent of their CVD much later. Similar low levels of awareness have been found among Indian medical students.[65] Lack of awareness could stem from the fact that medical professionals are not screened for CVD or the extent of their CVD is not assessed properly.[17,83] The overwhelming majority of Indian medical students are likely to be screened for CVD only at the time of entry to the MBBS course, accounting for their unawareness.[68] Moreover, those with less severe CVD learn to cope with their handicaps using cues or seeking help from others.[17,56,57,70] Finally, there is an element of denial, which might arise from the stigma associated with CVD and the fear that acknowledgement might hamper their careers.[12,13,96] Due to these concerns, students and doctors with CVD often project themselves as competent professionals even in the face of obvious difficulties.[17,68,96]

Choice of specialties

It has been proposed that CVD could pose special difficulties in certain specialties and cause less problems with others. Much of the evidence for this contention derives from the study of Spalding, where 23 doctors were asked about the specialties they would have avoided as students.[17,70,99] The specialties mentioned were histology, haematology, bacteriology, surgery, pathology, dermatology, anaesthesiology and retinal work in ophthalmology. The second piece of evidence derives from the studies listed in Table IV, which suggest that difficulties may be faced in microscopy (52%), chemical tests (30%), clinical examination (30%) and teaching methods (30%). This has been taken as evidence that doctors with CVD should avoid the specialties of histology, pathology, bacteriology, surgery, dermatology, ENT, anaesthesiology, emergency medicine, general practice, paediatrics, biochemistry and ophthalmology, while psychiatry, neurology and radiology should not pose problems.[11,17,56–58,68,70] However, it is obvious that such lists are not definitive because they are based on insufficient, anecdotal and selective evidence while ignoring the efforts that can be or are made by doctors with CVD working in different specialties.

Rights of medical professionals with CVD and avoiding discrimination

All over the world, there is growing awareness of the need to provide equal opportunities to those who have disabilities.[13,38] Although CVD does not strictly qualify as a disability, the need to avoid discriminating against individuals with CVD because of their deficiency is an important issue.[38] Any restriction of rights of those with handicaps can only be allowed if it can be conclusively demonstrated that they cannot meet the requirements of the job even after all help has been provided to mitigate effects of the deficiency, and/or that allowing such persons to work would compromise their safety or the safety of others. Based on the extant literature, it is evident that conclusive evidence linking CVD with occupational difficulties and risks is lacking. Rather,

TABLE IV. Difficulties associated with colour vision deficiency (CVD) among medical professionals

Study details	Results	Remarks
	Questionnaire-based studies	
Spalding (1997)[17] 40 doctors (37 GPs) who responded to letters were administered a 37-item questionnaire about difficulties faced in clinical practice and as students (for 23 doctors)	*As students:* difficulties faced in microscopy (52%), chemical tests (30%), clinical examination (30%), teaching methods (30%), identifying test strips (9%) *As doctors:* difficulties faced in identifying body colour changes (65%), skin changes (62%), charts, slides, prints and codes (60%), test-strips for blood and urine (55%), ophthalmoscopy (45%), blood or bile in urine, faeces, sputum or vomit (45%), otoscopy (35%), mouth and throat conditions (22%)	Severity of CVD was associated with the number of difficulties reported. Over 80% of the sample had moderate-to-severe CVD. Sample was self-selected
Agarwal et al. (2015)[63] 18 medical students with CVD on a questionnaire regarding problems faced in training and practice	None of the students faced any major difficulty in assessing and reading various diagnostic modalities, slides, charts and other clinical signs, which would markedly affect their diagnostic and treatment capabilities; only 3 of 18 students faced minor problems and needed professional help	Severity of CVD not reported
	Studies using colour-dependent material for testing medical skills	
Wilson (1885)[71] Accounts of 5 doctors with CVD	Detailed descriptions of difficulties with colour vision and its impact on daily life and medical practice	–
Tocantins and Jones (1933)[72] Skills in chemistry and microscopy of 70 medical students	9 with CVD made incorrect matches compared to controls in matching phenolphthalein solutions, identifying Gram-negative and acid-fast bacteria and eosinophils	–

(continued)

TABLE IV. Difficulties associated with colour vision deficiency (CVD) among medical professionals *(continued)*

Study details	Results	Remarks
Olson (1971)[73] 26 students with CVD out of 400 studying histology	Those with CVD had varying degrees of difficulty with the course material.	–
Vorster and Milner (1979)[74] 94 laboratory staff	6 with CVD unable to see acid-fast bacilli on a sputum smear; 2 could not identify colour of the glucose strips.	–
Rigby et al. (1991)[75] 30 volunteer histopathologists and cytopathologists	2 of the 3 with CVD had specific and major difficulties in identifying histological stains, particularly the more subtle stains.	–
Poole et al. (1997)[76] 270 male histopathologists and medical laboratory officers	18 subjects with CVD performed significantly worse than controls in correctly identifying projected transparencies of histopathology slides.	Those with severe CVD made more mistakes
Campbell et al. (1999)[77] 23 male GPs with CVD presented with photographs	Compared to 28 male controls, performance of those with CVD was significantly worse in assessment of normality and in their confidence about interpretation of photographs.	Sample from Spalding (1997)[17]
Campbell et al. (2000)[78] Assessment of colour-coded blood glucose testing stick in 23 male GPs with CVD	No differences between those with CVD and 28 male controls, but performance of doctors with severe CVD was significantly worse than that of controls.	Sample from Spalding (1997);[17] severity of CVD had greater impact on clinical skills
Reiss et al. (2001)[79] 10 with CVD (physicians, students, medical staff) presented with photographs of frank blood in stool, urine or sputum	Compared to 20 controls, those with CVD were significantly less able to correctly identify blood, particularly in stool samples. Only 10% of 21 physicians considered the possibility that CVD could affect patients' ability to detect blood, none enquired from patients.	Severity associated with lack of ability to identify blood
Campbell et al. (2004)[80] 23 GPs with CVD presented with photographs	Compared to 23 male controls, those with CVD had less ability and lacked confidence in detecting rashes and jaundice in the photographs and in naming colours.	Sample from Spalding (1997);[17] no association with severity of CVD
Campbell et al. (2005)[81] 22 male GPs with CVD presented with photographs	Compared to 17 male controls, performance of those with CVD was significantly worse in outlining abnormalities in photographs of fresh blood, rash and stained bacilli.	Sample from Spalding (1997);[17] those with severe CVD had more difficulties
Seki et al. (2005)[82] 20 microscopists assessed on slides of sputum and blood	Correct reading of diagnostic smears was associated with the colour vision ability of the technicians.	–
Dhingra et al. (2017)[68] 30 medical students with CVD versus 30 controls	Students with CVD committed more errors than controls when assessed with colour-dependent clinical and laboratory photographs and in detecting acid-fast bacilli on slides. Students with CVD were as confident as controls despite their obvious difficulties.	Nature of deficits indicated possible difficulties with certain specialties
	Direct observation	
Voke (1980)[83] Study of 102 endoscopists attending a conference	5 with CVD showed some errors in endoscopic skills assessed using a model stomach and circular-coloured targets compared to normal controls.	3 of the 5 with CVD felt handicapped
Koningsberger et al. (1994)[84] 139 gastroenterologists and internists screened with the F2 colour vision test	Assessment using a video excerpt of endoscopies of a variety of conditions showed that 15 with CVD were different from controls on only one relatively unimportant excerpt among the 9 excerpts administered.	CVD has no effect on endoscopic skills
	Dental students and dentists	
Shade selection	Compared to controls, those with CVD made significantly more errors in the hue and chroma aspects of shade selection affecting their ability to select prosthetic teeth to match natural teeth.[85–92]	–
	Subjective reports	
Several subjective reports by physicians on the impact of their own CVD	Though physicians had difficulties particularly in direct observation of physical signs, the impact on practice was variable. Poor awareness, lack of help and ability to compensate for deficits were highlighted.[11,12,17,70,93-98]	–

GPs general practitioners

the evidence suggests that with proper awareness most people with CVD will be able to work properly and safely.[42] Consequently, almost all professions that restrict employment of those with CVD are gradually relaxing their requirements for colour vision standards.[13,38,42] For doctors with CVD, the principle of equal opportunity translates as striking a balance between patient welfare with the necessity of equal and inclusive handling of those with CVD. Since the evidence connecting CVD with difficulties at work in the medical profession is even more scarce and debatable, avoiding unnecessary discrimination is a more pertinent concern.[92,96] The consensus view is that the presence of CVD should not be used to debar those who seek to become a part of the medical profession. Accordingly, apart from a few exceptions, medical courses all over the world do not exclude students with CVD. Alternatively, early detection, improving awareness, counselling to provide informational, emotional and practical help are not just ethical measures but realistic necessities in the practice of medicine.[11,57,68,70,100] Although there is a move away from whole-population screening for CVD, particularly at the school level, pre-vocational screening is still considered a justifiable measure.[13,21,22,42,101,102] Screening has been repeatedly recommended before entry to MBBS and is especially relevant in the Indian situation because those with CVD are considerably less likely to have been screened at any earlier stage.[68] Although several practical aids which could help doctors with CVD overcome their difficulties have been suggested, the only pragmatic way to help doctors with CVD is to make them aware of the nature and extent of their deficiency and offer constant support throughout their careers.[2,68,73,103] Unfortunately, it appears that the majority of doctors with CVD usually do not receive such help and support.[11,17,56,70,104] This shortcoming needs to be addressed by future research and practice in this area.

CONCLUSION

This overview of CVD shows that research on psychosocial aspects of CVD is rather limited, particularly regarding the impact of CVD on the medical profession. Obviously, much more needs to be done before making definitive statements on this sensitive issue. Nevertheless, the existing evidence, including data from general-population studies, highlights that some people with CVD including doctors may face difficulties in daily life and work. The nature and severity of CVD, awareness of its impact, personal circumstances and the ability to cope with colour vision deficits are the major factors that determine the eventual impact of CVD. Therefore, early detection, enhancing awareness and offering help will mitigate much of the adverse impact of CVD among those intending to or already pursuing a career in medicine. Such measures will also help in striking a balance between patient-related concerns and rights of doctors with CVD to fulfil their career-related ambitions. Thus, despite the scarcity of the evidence, it is possible to formulate a few broad and tentative recommendations given in Box 1.

Box 1. Colour vision deficiency (CVD): Recommendations for the medical profession

- There should not be any stringent requirement for students and doctors to have fully normal colour vision to pursue the medical profession both at the undergraduate and the postgraduate level.
- All entrants to medical profession should be screened for CVD using appropriate tests. Screening at the entry level assumes greater importance for Indian students because they are less likely to have been screened at any earlier stage.
- Those who screen positive should be tested extensively to determine the nature and severity of their CVD. Testing at this stage should ideally include their awareness of the condition, the psychological and social impact that CVD has had on their lives and their understanding of the difficulties likely to occur during the course of their future medical training.
- Such testing should be followed by education and counselling of those with CVD. Their awareness about the nature and severity of their CVD should be enhanced. They should receive advice on how to adapt to and cope with their deficiency so as to ensure safe medical practice.
- All students and doctors with CVD should receive ongoing psychological support and practical help to enable them to care for their patients safely and effectively throughout their careers. Adaptive strategies for overcoming the difficulties posed by CVD need to be encouraged and opportunities provided to practise these during training and at work.
- The choice of the specialty should be suited to the severity of CVD, the demands of the specialty, the extent of anticipated difficulties in performing clinical tasks related to that specialty, and the needs and expectations of individual trainees. It is hoped that with proper education and counselling most doctors will be able to make an informed and appropriate choice of the medical specialty they want to practise.
- At all stages, the guiding principle must be to strike a balance between the rights of an individual to pursue his/her chosen career path in medicine and the concerns about patient care, welfare and safety.
- The primary focus of any subsequent research effort should be to find ways of helping doctors with CVD to successfully adapt to their deficiency and the implementation of good practices in this area.

Conflicts of interest. None declared

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