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COLOUR VISION IMPAIRMENT IN WORKERS EXPOSED TO LOW CONCENTRATIONS OF TOLUENE

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Colour vision was examined by the Lanthony-D-15 desaturated test in 41 women exposed to toluene and in 29 non-exposed referents. Toluene exposure was evaluated by methods of environmental and biological monitoring. In the exposed group the median value of toluene in air was 35 ppm (range 11.2-49.9 ppm). Quantitative colour vision impairment was expressed as colour confusion index and colour confusion index corrected for alcohol intake. Qualitative impairment was expressed as normal, yellow-blue, red-green range or complex impairment. Statistical analysis showed the index values to be significantly correlated with age in both groups. In the exposed group they were significantly higher than in the non-exposed group. There was no significant difference in the prevalence of impairment in the blue-yellow range between the examined groups, although the prevalence of impairment in the exposed group was higher than in the non-exposed one. Results suggest that exposure to low toluene concentrations may induce colour vision impairment in women.

Key terms:
age, Lanthony-D-15 desaturated test, occupational
exposure in shoe factory

Acquired colour vision impairment has been associated with occupational exposure to n-hexane (1), 2-t-butylaso-2-hydroxy-5-methyl-hexane (2), carbon disulphide (3), organic solvent mixtures (4-11), styrene (12-15), and perchlorethylene (16).

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The Lanthony D-15-desaturated test is frequently used to identify colour vision impairment in workers exposed to organic solvents (17). It is a simple colour arrangement test for identification of mild acquired dyschromatopsia, and can be administered rapidly in standard conditions (5, 17).

Acquired colour vision impairment (dyschromatopsia) is known to be age (18-20) and alcohol (21) dependent and can be monocular (22). It has been reported to be due to the effects of digoxine (23) and has been associated with diabetes mellitus (24, 25). In this study the Lanthony-D-15 desaturated test was used to determine the chromatic discrimination capacity of workers occupationally exposed to low concentrations of toluene in comparison to those who were not exposed to solvents.

SUBJECTS AND METHOD

Two groups of workers were examined: a group occupationally exposed to toluene and a non-exposed control group. The exposed group consisted of 46 workers (43 women and three men) whose job was glueing shoe soles in a shoe factory where, traditionally, work is still carried out manually. During their working life they have been exposed to toluene. The control group comprised 36 workers (all women) employed in the confectionery industry, who were not occupationally exposed to solvents.

All the examined subjects completed a questionnaire on their habits, including smoking, weekly amount of alcohol intake, medications and hobbies or additional work in which they were engaged outside the workplace. Data on past or present diseases, eye diseases including congenital impaired colour vision and refraction anomaly of the eye, were obtained from case histories, medical records and a detailed medical examination of each subject.

Twelve subjects (five in the exposed, and seven in the control group) were excluded from the study for fear that hypertension (three exposed and one non-exposed), diabetes (two non-exposed), refractory anomaly (one exposed and one non-exposed), cataract of the lens (one exposed and one non-exposed), and hobbies requiring use of organic solvents (two non-exposed) could have an effect on colour vision.

Exposure assessment

In all the exposed women employed in the shoe factory, exposure was evaluated by environmental and biological monitoring of toluene. Air samples were collected at 11 stationary sampling locations. Sampling tubes with Cassella sampling pumps were attached to the working tables or machines at breathing level, and air was collected continually throughout the working day. The sampling flow was 100 ml/min⁻¹. The absorbed toluene on charcoal was desorbed with carbon disulphide and analysed by gas chromatography with a flame ionisation detector (26). A

sample for toluene determination in venous blood was taken on Wednesday morning before work. Toluene in blood was analysed by the method of Nise and Orback (27, 28).

At the time of study production in the shoe factory dropped because of the war in Croatia. All the exposed women worked with toluene for the last three years. Twenty women worked in toluene exposure for at least eight hours daily, 22 days a month for the last three years; in this subgroup work rhythm was classified as continuous. The other twenty-one women worked with toluene for less than six hours daily and less than five days a week for the last two years. The work rhythm in this subgroup was classified as periodic. Toluene-exposure duration was also calculated, for each subject, according to the formula: hours of daily exposure x the number of weeks in the year x the number of years = the number of hours of actual exposure.

Colour vision testing

Colour vision was tested by a Lanthony-15 Hue desaturated panel in standard conditions (5, 17). The test was carried out on Wednesday morning before the workshift in natural sunlight. The subjects who wore spectacles or contact lenses had them on during the testing. Each eye was tested separately. The test is based on the subject's ability to recombine a set of 15 desaturated colour caps according to a definite chromatic sequence. The score index, which expresses quantitative colour vision impairment, was calculated according to Bowman's method (29). Colour confusion index (CCI) for each subject was calculated using the method recommended by *Mergler and Blain* 1984 (5). Deviation from ideal CCI depended on the order in which each subject arranged the caps.

Qualitative colour vision was also evaluated, and the types of defects were analysed by errors axis in the yellow-blue and red-green ranges, or both, and classified according to chromal focuses as yellow-blue impairment, red-green impairment or complex impairment (6).

Alcohol consumption and cigarette smoking

Alcohol consumption was calculated according to *Thielly* (30). The author quantified the amount of alcohol: one litre of beer or half a litre of wine was taken to contain 44 g alcohol; a glass of beer or a liqueur glass of hard liquor contained 12.5 g alcohol. Cigarette smoking was calculated according to the formula: index of smoking = number of cigarettes/day x years of smoking (31).

Statistical analysis

Statistical analysis was carried out by means of the Statistics for Windows program. The normality of variables distribution was verified by the Kolmogorov-Smirnov test; the mean values between the groups were compared by t-test and

Mann-Whitney U-test. Correlations were established between CCI as dependent variable and toluene in air or blood, total years of work, number of hours of actual exposure, smoking index, age, weekly amount of alcohol as independent variables in the exposed group. In the non-exposed group, the same parameters with the exception of toluene exposure indicators, were used as independent variables. In both groups the correlation between RCCI as dependent variable and the same variables, except alcohol intake, as independent variables was also calculated.

In both groups, the correlation between qualitative colour vision impairment and all the above parameters, including work rhythm, was estimated by the Spearman's rank correlation test.

RESULTS

Characteristics of the examined groups are presented in Table 1. In the exposed group there were 24 women smokers (mean smoking index 470 ± 144 , range 120-560) and in the non-exposed group they were 12 (mean 458 ± 151 , range 120-620). There was no significant difference in the smoking index between the smokers in the two groups. In the exposed group 14 women consumed alcohol (mean 86.3 ± 83.0 , range 15.0-300.0). There were no significant differences concerning this parameter in the examined groups.

Table 1 Characteristics of examined groups

Group	Age (years)	Duration of work (years)	Actual exposure (hours)	Cigarette smoking* (index)	Alcohol intake* (g/week)
Exposed (n=41)	40.90 ± 7.51	19.90 ± 7.10		461.28 ± 103.22	86.53 ± 94.71
Continually (n=20)	40.80 ± 6.50	18.40 ± 6.50	23614.50 ± 9273.66^a	460.50 ± 101.72	82.33 ± 96.97
Periodically (n=21)	19.24 ± 7.52	19.24 ± 7.52	8750.00 ± 3798.87^b	462.77 ± 110.58	89.25 ± 96.52
Non-exposed (n=29)	19.20 ± 6.92	19.20 ± 6.92		418.27 ± 115.30	92.48 ± 55.67

^{a,b} $P < 0.05$

* only consumers

Legend: arithmetical means \pm standard deviation

Table 2 Indicators of toluene exposure in examined groups

Indicator	Exposed group (n=41)	Non-exposed group (n=29)	P
Toluene in air (ppm)	35.00 (11.44 - 49.92)	-	-
Toluene in blood (mg/ml) ^{DL}	0.36 (0.009 - 0.879)	0 (0.0 - 0.0019)	<0.05

P=significance of difference (Mann-Whitney U-test)
 Values are expressed as medians and ranges
 DL - detection limit (toluene = 0.0014 mg/ml)

For the subgroup of 20 women who worked continually with toluene, the time of actual exposure was 2361±49723 hours (range 10500-38500). For the subgroup of women who were exposed to toluene periodically at work the time of actual exposure was 16359±3799 hours (range 8750-21250). The difference between the subgroups was statistically significant (P<0.05).

In the exposed group the median CCI value was 1.27 (range 1.00-1.58), and in the non-exposed group 1.17 (range 1.00-1.38). The difference between the groups was significant (P<0.05). There were no significant differences in CCI value between alcohol consumers and non-consumers or between smokers and non-smokers in the exposed group. There was likewise no difference in CCI value between workers periodically exposed to toluene and those who continually worked in toluene exposure.

In both the exposed and the non-exposed groups only age was statistically significantly correlated to CCI (Figure 1).

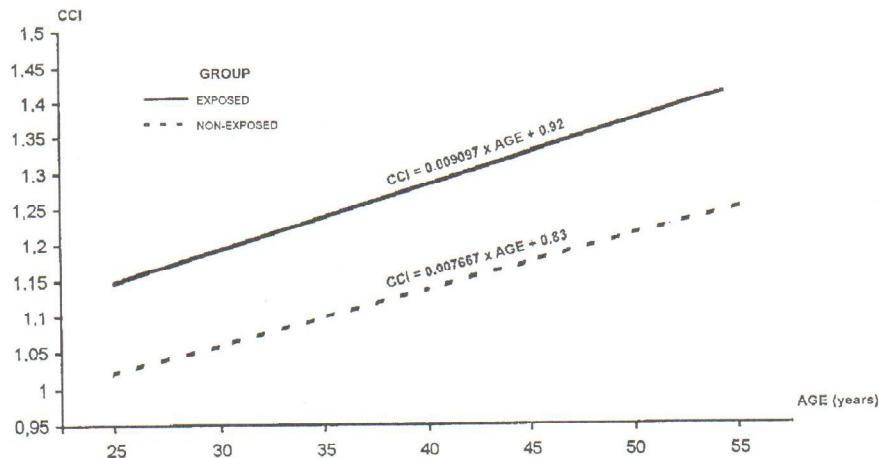


Figure 1 Colour confusion index (CCI) in relationship to age

The slope of the regression line was steeper in the group exposed to toluene compared to the non-exposed group, but the difference was not significant.

Knowing that alcohol can be a major confounding factor in acquired colour vision impairment, the CCI was corrected for alcohol intake on the basis of alcohol intake in the non-exposed group. The formula for residual of CCI (RCCI) was:

$$RCCI = CCI - (1.129 + 0.000595 \times \text{alcohol intake}).$$

There was a significant difference in the RCCI value between the examined groups ($P < 0.05$). In both groups RCCI also correlated only with age (Figure 2), and the slope of the regression line was steeper in the toluene exposed group.

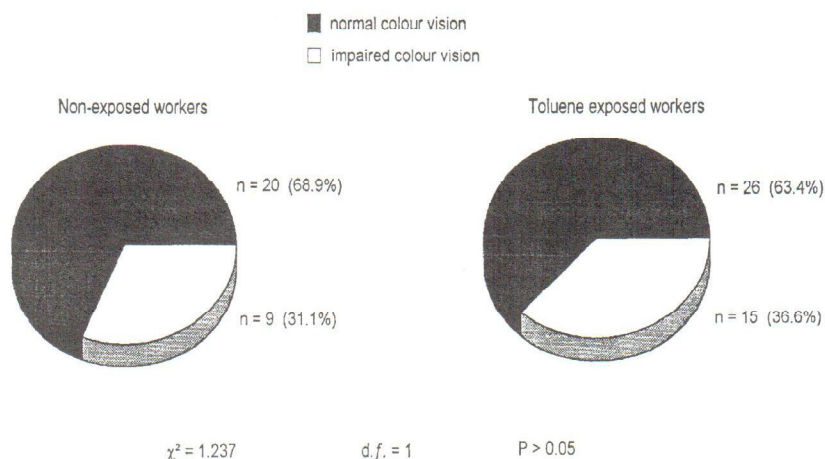


Figure 2 Qualitative colour vision in examined groups

In control group nine (31%) women were found to have a yellow-blue range impairment and 20 (69%) had normal colour vision. In the exposed group the yellow-blue range was impaired in 14 (34%) women, one (2%) had a complex impairment, and 26 (63%) had normal colour vision.

There was no significant difference in the prevalence of impairment in the yellow-blue range between the groups, although the prevalence in the exposed group was higher than in the non-exposed one.

In both groups the impairment in the yellow-blue range showed a statistically significant correlation with age ($r = 0.492$; $P < 0.05$ and $r = 0.7682$; $P < 0.0001$, respectively). No significant correlation was found between the impairment in the yellow-blue range and markers of toluene exposure, weekly alcohol intake, cigarette smoking, or work rhythm in the exposed group, or between the same impairment and weekly alcohol intake or cigarette smoking in the non-exposed group.

DISCUSSION

In this study the CCI value was significantly higher in the exposed group than in the non-exposed one ($P < 0.05$). Although in both examined groups weekly alcohol intake was actually very low (see Table 1), we corrected CCI for alcohol intake, because alcohol could be a confounding factor in acquired colour vision impairment (21). The corrected CCI - RCCI was also significantly higher ($P < 0.05$) in the exposed group than in the non-exposed one. In toluene exposed workers the slope of the regression line between CCI and age was steeper than in non-exposed workers, but the difference was not significant. The same result was also found for the RCCI value. *Gobba and co-workers* (12) also confirmed that in styrene exposed workers this line was steeper than in non-exposed workers. In this study toluene was the distinguishing factor between the groups, and this suggests a possible additive effect of toluene exposure on CCI and RCCI values in exposed women. Numerous authors (4, 18-22) have also found a significant correlation between age and CCI values in workers exposed to solvents as well as in those who were not exposed, although *Scholz and co-workers* (33) failed to confirm such correlation. In this study no significant correlation was found between the hours of actual exposure to toluene and CCI or RCCI values.

Many authors confirm statistically significant correlations between CCI values and the environmental concentration of solvents or solvent mixtures, as well as between the CCI value and the solvent concentration in blood (5, 6, 12). In this study such correlation was not established. This difference can be explained by the low concentrations and slight variability in air and/or blood toluene in the relatively small sample. Another reason could be that the airborne levels were not completely representative of individual exposure, having been recorded at stationary sampling locations, or because workers refused to cooperate twice and toluene concentrations were only measured before the workshift but not after it.

In two groups of workers exposed to diethyl ether *Mergler and Blain* (6) established that the prevalence of impairment in the blue-yellow range was in correlation with the solvent concentrations. Consequently, the prevalence of impairment in the yellow-blue range in workers exposed to diethyl ether concentrations higher than 2000 mg/m^3 was significantly higher ($P < 0.05$) than in the control group or in those exposed to diethyl ether concentrations below 1000 mg/m^3 . *Mergler and Blain* also established a significant correlation between yellow-blue impairment and age (6). In this study, significant correlation was established between age and yellow-blue impairment for solvent exposed workers as well as for the solvent non-exposed ones, but a difference between the groups, like in the study by *Nakatsuka and co-workers* (32) was not established.

Exposed and non-exposed women were also classified according to cigarette smoking. No effect of cigarette smoking on CCI and RCCI values, or on the impairment in the yellow-blue range was observed.

Our results show a significant correlation between age on the one hand and CCI and RCCI values and the yellow-blue range impairment on the other in both examined groups. Although toluene in air/or blood was not completely representative of actual individual exposure in this study, the results suggest the

possibility that exposure to low toluene concentrations can induce colour vision impairment in women.

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Sažetak

OŠTEĆENJE VIDA ZA BOJE U RADNICA IZVRGNUTIH NISKIM RAZINAMA TOLUENA

Desaturacijskim testom Lanthony D-15 ispitivan je vid za boje u 41 radnice izvrgnute prosječnoj koncentraciji toluena u zraku od 35 ppm (raspon 11,2-49,9 ppm) i u 29 radnica kontrolne skupine. Kvalitativni vid za boje izražen je kao indeks pogreške i kao indeks pogreške korigiran za utjecaj alkohola, a kvalitativni vid kao normalan, s oštećenjem u plavo-žutom dijelu spektra ili kao složeno oštećenje. Rezultati su statistički analizirani t-testom i Mann-Whitneyevim U-testom. U obje su ispitivane skupine vrijednosti indeksa pogreške i indeksa pogreške korigiranog za utjecaj alkohola bile značajno povezane s dobi ispitanika. U skupini izloženoj toluenu njihove su vrijednosti bile statistički značajno više (P) nego u kontrolnoj skupini. Nije bilo statistički značajno učestalijeg oštećenja vida u žuto-plavom dijelu spektra. Rezultati upućuju na zaključak da u radnica izvrgnutih niskim koncentracijama toluena indeks pogreške značajno odstupa od očekivanoga, ali da kvalitativno oštećenje vida za boje nije učestalije nego u poredbenoj skupini.

Ključne riječi:

dob, desaturacijski test Lanthony D-15, profesionalna izloženost u tvornici cipela

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