Drug and Alcohol Dependence 194 (2019) 197–204

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Full length article

Use of the Fagerström test to assess differences in the degree of nicotine dependence in smokers from five ethnic groups: The HELIUS study

Jan van Amsterdam[a], Florence Vorspan[b,c], Marieke B. Snijder[d], Wim van den Brink[a], Aart H. Schene[e,f], Karien Stronks[d], Henrike Galenkamp[d], Eske M. Derks[g,*]

[a] Department of Psychiatry, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands
[b] Assistance Publique – Hôpitaux de Paris, Fernand Widal Hospital, Department of Psychiatry and Addiction Medicine, Paris, France
[c] INSERM UMR-S1144, Paris, France
[d] Department of Public Health, Amsterdam Public Health (APH) research institute, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands
[e] Department of Psychiatry, Radboud University Medical Center, Nijmegen, the Netherlands
[f] Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, the Netherlands
[g] Translational Neurogenomics group, QIMR Berghofer, Brisbane, Australia

ARTICLE INFO

Keywords:
FTND
Smoking
Dependence
Measurement invariance
Factor analysis
Ethnicity
HELIUS study

ABSTRACT

Background: The prevalence of smoking varies across ethnic groups in developed countries, but little is known about ethnic variations in specific aspects of nicotine dependence (ND). We conducted item-response analyses in current smokers to compare ND factors across five ethnic groups.
Methods: Data were obtained from a population-based, multi-ethnic cohort study conducted in the Netherlands. The Fagerström Test for Nicotine Dependence (FTND) was assessed in 1147 Dutch, 991 South-Asian Surinamese, 1408 African Surinamese, 1396 Turkish, and 584 Moroccan smokers (N = 5526). We tested whether the factorial structure of the FTND was invariant across ethnic groups using a multi-group confirmatory factor analysis. FTND item and total scores and factor means were compared across groups.
Results: The two-factor model representing "morning smoking" and "smoking patterns" provided an adequate fit. The items "Cigarettes smoked daily" and "Time until first cigarette" showed differential item functioning (DIF) as a function of ethnicity. Three out of four ethnic minority groups scored significantly higher on both factors compared to the Dutch origin group (all $p < 0.001$) before and after taking DIF into account, while the African Surinamese scored higher only on "morning smoking" when DIF was accounted for.
Discussion: The factor structure of the FTND is not measurement invariant across ethnic groups in this population-based sample. Accounting for DIF affecting the nicotine dependence factor scores, although South-Asian Surinamese, Turkish, and Moroccan groups showed higher levels of dependence than the Dutch origin group, genetic as well as environmental factors may account for the observed differences.

1. Introduction

The prevalence of smoking varies greatly across countries. Western European countries, such as the Netherlands, have intermediate prevalence (Ng et al., 2014) while the estimated prevalence of daily smoking in men is relatively low in African countries. At a global level, women smoke consistently less than men (Ng et al., 2014). Similar differences across ethnic populations are observed within immigrant populations in high income countries. For example, one study performed in three immigrant populations in the Netherlands showed that the prevalence of smoking is higher in Turkish and Surinamese origin men (63% and 55%, respectively) than in Moroccan men (30%) (Nierkens et al., 2006). Furthermore, a study recently performed in the U.K. showed that some immigrant groups, especially those from Eastern European countries such as Turkey and Greece, had higher smoking rates than subjects born in the U.K. (Aspinall and Mitton, 2014).

Provided that there are large differences in smoking rates across ethnic populations, the question arises whether there are also ethnic differences in the levels of nicotine dependence (ND) among smokers. Liability for ND in smokers may differ across ethnic groups as there may be variations in sociocultural factors (e.g., religiosity, smoking acceptability, or education), psychological factors [e.g., perceived discrimination (Visser et al., 2017) and personality traits (Choi et al., 2017)], affordability, and biological factors (Benowitz et al., 2006;

* Corresponding author: Translational Neurogenomics Group QIMR Berghofer, Brisbane, Australia.
E-mail address: eske.derks@qimrberghofer.edu.au (E.M. Derks).

https://doi.org/10.1016/j.drugalcdep.2018.10.011
Received 6 July 2018; Received in revised form 3 October 2018; Accepted 9 October 2018
Available online 06 November 2018
0376-8716/

Sullivan and Kendler, 1999). In the present study, we will explore ethnic differences in the different components of ND in smokers across ethnic groups.

The HELIUS study (Healthy Life in an Urban Setting; a large multi-ethnic cohort study) investigates health differences in cardiovascular disease, infectious disease, and mental health among the six largest ethnic groups in Amsterdam, the Netherlands, i.e.: South-Asian Surinamese, African Surinamese, Ghanaian, Turkish, Moroccan, and Dutch (Stronks et al., 2013). Within the HELIUS study, Visser et al. (2017) showed that, compared to the Dutch origin group, smoking rates were higher in Turkish (OR = 1.59), South-Asian Surinamese (OR = 1.31), African Surinamese (OR = 1.59), but lower in Ghanaian (OR = 0.14) and Moroccan (OR = 0.47) origin groups. Compared to Dutch origin smokers, the prevalence of ND was higher in Turkish (OR = 2.09), Moroccan (OR = 1.85), and South-Asian Surinamese participants (OR = 1.79), whereas it was similar in African Surinamese (OR = 0.89) and Ghanaian (OR = 0.95) smokers.

In the HELIUS study, ND was assessed with the Fagerström Test For Nicotine Dependence (FTND), one of the most widely used instruments to assess dependence (Heatherton et al., 1991). The FTND has been shown to be a better predictor of ND and smoking quit rate compared to the number of cigarettes per day or the number of years of smoking (John et al., 2003). Among different scales aimed at assessing ND, it has the strongest correlation with withdrawal symptoms and relapse to smoking because of withdrawal symptoms (DiFranza et al., 2012; Fagerström and Furberg, 2008; Moolchan et al., 2002; Rios-Bedoya et al., 2008). In some studies, the FTND is composed of one factor (Chabrol et al., 2003; Heatherton et al., 1991), while in other studies, there are two factors, labelled as “Smoking Pattern” and “Morning Smoking,” (Steinberg et al., 2005; Richardson and Ratner, 2005; Radzius et al., 2003; Jhanjee and Sethi, 2010; Haddock et al., 1999).

In the present study, we will extend the earlier work by Visser et al. (2017) and explore ethnic differences in the factor structure and the item characteristics of the FTND. To be able to make a meaningful comparison regarding ND across different ethnic subgroups, it is essential to establish that the FTND is a valid instrument in all ethnic groups by testing whether the factor structure is invariant across groups. Earlier studies have indicated that the factor structure of the FTND may be different across ethnic groups. The factor structure of the FTND was found to be different in a sample of white and African-American adolescents (Schroeder and Moolchan, 2007) and in a community-based sample of European and African American current and former adult smokers (Johnson et al., 2008). As far as we are aware, no studies have investigated measurement invariance of the FTND in ethnic minority groups within Europe.

The aim of this study was to investigate whether the factorial structure of the FTND is similar across five different ethnic groups monitored by the HELIUS study group. Participants with Ghanaian background were excluded because of low smoking rates in the Ghanaian population (11.7%). Since the number of factors was found to be inconsistent in earlier studies, we will compare the fit of one- and two-factor models. After establishing whether the FTND is measurement invariant amongst ethnic groups, the second aim of this study is to investigate differences in the levels of ND at the level of the underlying factor(s).

2. Methods

2.1. Study design

We used baseline data from the Healthy Life in an Urban Setting (HELIUS) study, a multi-ethnic cohort study in Amsterdam (Snijder et al., 2017; Stronks et al., 2013). In brief, the HELIUS study is a large prospective cohort study, which aims to unravel the causes behind the unequal burden of disease among the largest ethnic groups in Amsterdam. The study was carried out by the Academic Medical Center (AMC) at the University of Amsterdam and the Municipal Health Service of Amsterdam, and baseline data were collected in 2011-2015. Subjects were randomly sampled, stratified by ethnicity, from those aged 18–70 years listed in the municipality register of Amsterdam (Snijder et al., 2017; Stronks et al., 2013). Data were collected by questionnaire and a physical examination, and biological samples were obtained during the physical examination. The study protocols were approved by the AMC Ethical Review Board, and all participants provided written informed consent.

2.2. Sample

Questionnaire data were obtained from 23,942 participants. Among them, FTND scores were available for 23,645 participants, of which 19.5% were of Dutch ethnicity (N = 4616), 14.0% of South-Asian Surinamese ethnicity (N = 3322), 18.5% of African Surinamese ethnicity (N = 4379), 16.9% of Turkish ethnicity (N = 3998), 18.2% of Moroccan ethnicity (N = 4302), and 10.4% of Ghanaian ethnicity (N = 2452). The remaining 2.4% (N = 576) were from other or unknown ethnicities and were not included in this study. Since the aim of the present paper is to compare the factor structure of the FTND across smokers of five ethnic groups, analyses were limited to current smokers who completed the FTND. Due to low smoking rates in the Ghanaian population, i.e., only 288 (11.7%) participants from Ghana were current or past smokers while only 91 completed the FTND, we excluded this group from subsequent analyses. The number of participants by ethnic group were: Dutch: 1147; South-Asian Surinamese: 991; African Surinamese: 1408; Turkish: 1396 and Moroccan: 584. The total sample size comprised 5526 participants.

2.3. Variables

2.3.1. Ethnicity

Ethnicity was defined according to country of birth of the participants as well as that of their parents (Stronks et al., 2009). This country of birth indicator is the Dutch standard indicator for ethnic origin. It has the advantage of being objective and stable over time, and cross-validation studies showed a high correlation between the country of birth indicator and self-identified ethnic group indicator among Turkish, Moroccan and Surinamese people in the Netherlands (Stronks et al., 2009). Specifically, a participant was considered of non-Dutch ethnicity if either of the following criteria was fulfilled: (1) born outside the Netherlands and at least one parent born outside the Netherlands (i.e., first generation); or (2) born in the Netherlands, but both parents born outside the Netherlands (i.e., second generation). A limitation of the country of birth indicator for ethnicity is that people who are born in the same country might have a different ethnic background, which in the Dutch context is applicable to the Surinamese population (Stronks et al., 2009). Of the Surinamese immigrants in the Netherlands, approximately 80% are either of African or South-Asian origin and they were classified according to self-reported ethnic origin. Therefore, after data collection, participants of Surinamese ethnic origin were further classified according to self-reported ethnic origin (obtained by questionnaire) into ‘African,’ ‘South-Asian,’ or ‘other.’ For the Dutch group, we invited people who were themselves, as well as both their parents, born in the Netherlands.

2.3.2. Nicotine use and dependence

To assess ND, we used the six-item Fagerström Test for Nicotine Dependence (FTND) which has a graded scale (0–10) corresponding to the degree of ND (Heatherton et al., 1991; Payne et al., 1994). If one of the six items was missing, the Fagerström score was calculated with the missing item calculated as zero (0). If more than one item was missing, the Fagerström score was not calculated and coded as missing. A score of ≥ 4 and < 8 was used to define light ND while a cut-off ≥ 8 was defined as strong ND (Fagerstrom et al., 1992). Although it has been

proposed to change the name of this instrument to "Fagerström Test for Cigarette Dependence (FTCD)" (Fagerström, 2012), we have not adapted the new terminology since we also assessed smoking of tobacco products other than cigarettes.

2.3.3. Educational level

Educational level, based on the highest education obtained, either in the Netherlands or in the country of origin, was categorized into: no education or elementary education only; lower vocational or lower secondary education; intermediate vocational and intermediate/higher secondary education; and higher vocational education or university.

2.4. Statistical analyses

Except for the multi-group factor analyses, all statistical analyses were performed in SPSS Statistics version 22 (IBM, 2016). Where appropriate, results are represented as standardized betas.

2.4.1. Comparison of sociodemographic factors

We investigated whether demographic factors were significantly associated with ethnicity using ANOVA (age), or X^2 tests (sex and educational level). We subsequently tested the influence of these demographic factors on total FTND scores in a linear regression analysis with FTND scores as the dependent variable, and age, sex, educational level, and ethnicity as independent variables. Ethnicity and educational level were dummy coded. For these exploratory analyses, we used a significance level of $p < 0.05$.

2.4.2. Comparison of number of cigarettes per day, ND, and item scores across ethnic groups

We evaluated the impact of ethnicity on the number of cigarettes smoked per day using ANOVA. We also tested whether nicotine dependence rates (no dependence; light dependence; strong dependence) were significantly associated with ethnicity in an ordinal regression analysis. We tested whether item endorsement rates were significantly different across ethnic groups, using either ordinal regression analysis for the ordinal items or logistic regression analysis for the binary items. Finally, we used an ANOVA to test whether mean FTND scores are significantly different across groups. These analyses all included age and sex as covariates. Since we compared ethnic differences in nine phenotypes (*six FTND items, mean number of cigarettes per day, total FTND score and categorical FTND score)* and compared four ethnic groups against the Dutch origin reference group, we used Bonferroni correction to control the type-I error rate, and evaluated test results at a significance level of $p < 0.0014$.

2.4.3. Factorial structure analysis

Configural, metric, strong, and strict factorial invariance were successively assessed to evaluate measurement invariance (MI) across ethnic groups (Muthén and Asparouhov, 2002). The FTND item scores of all samples were compared within a multi-group confirmatory factor analysis (CFA) using Theta parameterization. The Weighted Least Squares Means and Variance (WLSMV) estimator for non-normally distributed data in Mplus Version 5.1 was used for statistical analysis with latent variables (Muthén and Muthén, 2010). Goodness of model fit of the baseline model (i.e., the model which imposes least constraints to the similarity of the factor structures) was determined by the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA) (Bentler, 1990; Bollen and Long, 1993). These indexes compare the observed sample covariance matrices with the estimated covariance matrices of the factor model. The RMSEA has the advantage that it performs well with categorical data and is reasonably insensitive for the number of observations in the sample (Hu and Bentler, 1995; Schermelleh-Engell et al., 2003). We applied cut-offs defined by Rutkowski and Svetina (2018) who performed simulation studies in a situation comparable to the current study (i.e., large sample size, ordinal variables) and showed that relatively strict cut-offs of RMSEA < 0.055 and CFI > 0.97 indicate good model fit.

In the configural invariance model, only the pattern of factor loadings was constrained to be identical across groups. The factor loadings were allowed to be different across ethnic groups. The model was identified by: (1) constraining the factor variances at one in all ethnic groups; (2) constraining the factor means at 0 in the Dutch reference group (factor means were freely estimated in the other ethnic groups); (3) constraining the first threshold of all items to be equal across all ethnic groups (for identification of residual item variances); and (4) constraining the second threshold of an additional item per factor to be equal across all ethnic groups (for identification of factor means in non-reference groups). Both a one-factor model and a two-factor model as described by Richardson and Ratner (2005) were used as baseline models. In the two-factor model, the items "Time until first cigarette," "Hate to give up your first cigarette of the day," "Smoke more frequently during the first hours after waking" load on factor 1 (Morning Smoking), while the items "Time until first cigarette," "Number of cigarettes smoked daily," "Difficult to keep from smoking in places where it is not allowed?" and "Do you smoke if you are so ill that you are in bed most of the day?" load on factor 2 (Smoking Pattern). The factors were allowed to correlate.

If one of these models provided an acceptable fit in all ethnic groups, the model was said to show configural invariance with respect to ethnicity which implies that in all groups the FTND items load on the same factors. After establishing goodness of fit of the configural invariance model, increasingly stringent model constraints were applied to test the remaining levels of measurement invariance. The second step in the MI analysis was to test for metric invariance (Horn and McArdle, 1992). Metric invariance was investigated by constraining the factor loadings of the factor model to be equal across all ethnic groups while freely estimating the factor variances in the non-reference groups. Subsequently, item thresholds were equated across ethnic groups to assess strong factorial invariance. In the final step, strict factorial invariance was tested by including an equality constraint to the residual variances of the items. In this way, it was tested whether the measurement accuracy is equal across ethnic groups. Only if all four levels of MI are confirmed, can differences in observed scores be interpreted as differences in unobserved latent scores.

2.4.4. Associations between FTND factor scores and ethnicity

We used the SAVE = fscores option in MPLUS to save the factor scores to a text file and subsequently analysed these in SPSS. We saved the factor scores estimated in a model that does not allow for differential item functioning (DIF) and those estimated in a model that does take DIF into account by releasing some of the constraints. For both factors F1 and F2 and for each of the two models, we performed linear regression analyses, with the factor scores as the dependent variables. Ethnicity, age, and sex were included as independent variables. Significance was evaluated at a significance level of $p < 0.0625$ controlling for eight independent tests (four tests per factor). We did not correct for the two models that we evaluated as the results of these tests will be highly correlated.

3. Results

3.1. Sociodemographic factors

Table 1 shows the distribution of age, sex, and educational level across ethnicities. The following population characteristics were significantly different across ethnic groups: age ($F(4,5525) = 119.65$, $p < 0.001$), sex ($X^2(4) = 143.30$, $p < 0.001$), and educational level ($X^2(12) = 901.11$, $p < 0.001$). Controlling for ethnicity, age was positively associated with total FTND scores (standardized $B = 0.09$, $p < 0.001$). FTND scores were significantly lower in women (standardized $B = -0.07$, $p < 0.001$) and in those with intermediate

Table 1
Demographic data, smoking behaviour and dependence rate among smokers, by ethnicity. SD in parenthesis if not indicated otherwise.

		Dutch (N = 1147)	South-Asian Surinamese (N = 991)	African Surinamese (N = 1408)	Turkish (N = 1396)	Moroccan (N = 584)
Mean age (yrs.)		44.22 (14.13)	43.78 (13.06)	47.11 (12.25)	38.18 (11.19)	37.68 (11.34)
% Female		51.8	36.3	45.0	46.0	24.5
Educational level						
Level 1 (lowest) (%) *		5.1	17.0	7.5	25.4	18.0
Level 2 (%)		20.3	37.4	42.0	32.2	27.9
Level 3 (%)		25.3	30.0	34.5	31.2	36.5
Level 4 (%)		48.8	15.3	15.1	10.5	17.1
Missing/Unknown		0.4	0.3	0.8	0.7	0.5
Number of cigarette smokers (%)		1062 (92.6)	943 (95.2)	1207 (85.7)	1329 (95.2)	550 (94.2)
Cigarettes smoked per day (mean)**	All	10.0 (8.5)	9.7 (7.3)	8.8 (7.2)	12.8 (8.5)	11.7 (7.6)
	Males	10.5 (8.9)	10.4 (7.7)	9.3 (7.7)	14.5 (9.2)	12.9 (7.8)
	Females	9.6 (8.1)	8.4 (6.2)	8.3 (6.5)	10.8 (7.0)	8.0 (5.7)
Number of cigar smokers (%)		91 (7.9)	81 (8.2)	304 (21.6)	55 (3.9)	28 (4.8)
Cigars smoked per week (mean)**	All	18.9 (24.2)	22.37 (28.7)	13.3 (17.9)	24.4 (29.7)	30.6 (25.2)
	Males	17.8 (22.4)	20.2 (28.7)	12.4 (16.2)	30.1 (34.1)	33.4 (24.5)
	Females	25.4 (33.1)	27.4 (28.9)	14.3 (19.7)	14.6 (16.1)	20.2 (27.2)
Number of pipe smokers (%)		26 (2.3)	199 (20.1)	230 (16.3)	61 (4.4)	30 (5.1)
Packages of pipe tobacco smoked per week (mean) **	All	2.2 (1.7)	3.1 (3.1)	2.4 (1.8)	2.8 (2.1)	2.9 (2.3)
	Males	1.8 (1.0)	3.2 (3.1)	2.5 (1.8)	2.6 (1.8)	2.9 (2.4)
	Females	3.2 (3.0)	2.0 (0.9)	2.1 (1.6)	3.0 (2.5)	3.0 (1.8)
Nicotine dependent						
Not (%)	All	74.2	60.2	75.1	59.7	61.5
Light (%)	All	23.8	35.3	22.7	36.0	35.6
Strong (%)	All	2.0	4.4	2.2	4.3	2.9
Not (%)	Males	75.2	56.9	73.4	55.3	57.4
Light (%)	Males	22.6	37.6	24.2	39.8	38.8
Strong (%)	Males	2.2	5.5	2.5	4.9	3.9
Not (%)	Females	73.2	66.1	77.1	65.0	74.1
Light (%)	Females	24.9	31.4	21.0	31.5	25.9
Strong (%)	Females	1.9	2.5	1.9	3.6	–

* 1: no education or elementary education; 2: lower vocational and lower secondary education; 3: intermediate vocational and intermediate/higher secondary education; 4: higher vocational education or university. **: in smokers.

(standardized B = -0.092; $p < 0.001$) or higher educational level (standardized B = -0.18; $p < 0.001$) compared to "no education or elementary education" (results not shown).

3.2. A comparison of number of cigarettes per day and ND across ethnic groups

The number of cigarettes smoked per day ("Cigarettes smoked daily") differed significantly across ethnic groups while controlling for age and sex ($F(4,5062) = 47.80$, $p < 0.001$) with more cigarettes per day in Turkish and Moroccan participants and slightly fewer cigarettes per day in South-Asian and African Surinamese participants compared to the Dutch group (see Table 1 for unadjusted rates). Only a minority of each group reported smoking cigars or pipe tobacco. Table 1 also provides the rates of absent, light and strong ND as defined by FTND scores in the five ethnic groups. Controlling for age and sex, three minority groups (South-Asian Surinamese, Turkish, and Moroccan) displayed higher rates of light and strong ND than the Dutch group (all $p < 0.001$). Differences were more pronounced in men compared to women. No difference in ND was observed between Dutch and African Surinamese participants ($p = 0.27$).

3.3. A comparison of FTND item scores and total FTND scores across ethnic groups

The endorsement rates per item, unadjusted for age or sex are shown in Table 2. Logistic (for binary items) and ordinal (for items with more than two categories) regression analyses were conducted to test for ethnic differences, controlling for age and sex. Results were generally consistent across items. Compared to the Dutch group, the African Surinamese group showed slightly higher (Q1 and Q2; $p < 0.001$) or non-significant (Q3-Q6) endorsement differences. Item endorsements of all items were higher in the remaining three ethnic minority groups compared to the Dutch group (all $p < 0.001$; except for Q4 in the Moroccan group which is not statistically different at $p = 0.009$).

A comparison of mean FTND scores, correcting for age and sex, showed significant differences across the five ethnic groups ($F(4,5525) = 59.89$, $p < 0.001$). An inspection of mean scores revealed that participants of Dutch and African Surinamese origin scored relatively low on the FTND (mean scores of 1.97 and 2.18, respectively) while South-Asian Surinamese (mean = 3.02), Turkish (mean = 2.97) and Moroccan (mean = 2.86) participants obtained the highest scores.

3.4. Factorial structure analysis

Configural invariance of the FTND with respect to ethnicity was confirmed as the model that included two factors (i.e., representing "morning smoking" and "smoking pattern") provided an acceptable fit to the data in all five ethnic groups. The 1-factor model did not provide an adequate fit. A multi-group factor analysis, in which factor loadings were allowed to be different across the five different ethnicities provided a good fit to the data (RMSEA = 0.042; CFI = 0.993) which further confirmeds that configural invariance holds. However, the metric invariant model did not provide a good model fit (RMSEA = 0.064; CFI = 0.976). Exploration of modification indices showed that adding a correlation between the items "Cigarettes smoked daily" and "Time until first cigarette" and allowing this correlation to be different across ethnic groups resulted in a good-fitting model (RMSEA = 0.051, CFI = 0.986). Similarly, the strong invariance model did not provide a good fit to the data (RMSEA = 0.065, CFI = 0.972). Again, inclusion of a residual correlation between the items "Cigarettes smoked daily" and "Time until first cigarette" which was not constrained to be equal among the five ethnic groups, resulted in a good

Table 2
Mean unadjusted total FTND scores (SD) and endorsement rates (%) of individual FTND items by ethnicity* in smokers.

			Dutch (N = 1147)	South-Asian Surinamese (N = 991)	African Surinamese (N = 1408)	Turkish (N = 1396)	Moroccan (N = 584)
Q1	Time until first cigarette (%)	> 60 min	53.6	44.9	34.5	38.3	39.1
		31-60 min	12.4	17.5	14.9	18.4	19.6
		6-30 min	24.5	26.3	29.6	26.6	29.3
		< 5 min	9.5	11.2	21.0	16.6	12.0
Q2	Hate to give up your first cigarette of the day (% yes)		18.6	22.9	34.5	30.0	39.0
Q3	Smoke more frequently during the first hours after waking than during the rest of the day? (% yes)		10.8	10.7	18.4	20.1	15.8
Q4	Cigarettes smoked daily (number)	0-10	64.6	65.7	56.8	50.4	53.4
		11-20	26.8	21.7	25.2	37.7	40.3
		21-30	6.6	5.9	8.4	8.7	3.7
		> 30	2.0	6.7	9.7	3.1	2.7
Q5	Difficult to keep from smoking in places where it is not allowed? (% yes)		10.7	9.5	15.9	30.2	25.8
Q6	Do you smoke when you are so ill that you are in bed most of the day? (% yes)		19.0	17.9	26.0	32.1	35.2
	Mean total Fagerström score (SD)		1.97 (2.35)	2.18 (2.24)	3.02 (2.52)	2.97 (2.52)	2.86 (2.36)

* Corrected for age and sex.

Table 3
Parameter estimates of the final model.

		All ethnic groups	Dutch	South-Asian Surinamese	African Surinamese	Turkish	Moroccan
Factor loadings F1	Q1. Time until first cigarette	2.03					
	Q2. Hate to give up your first cigarette of the day	1.02					
	Q3. Smoke more frequently during the first hours after waking	1.05					
Factor Loadings F2	Q1. Time until first cigarette	−0.15					
	Q4. Cigarettes smoked daily (Number)	0.95					
	Q5. Difficult to keep from smoking in places where it is not allowed?	1.43					
	Q6. Do you smoke if you are so ill that you are in bed most of the day?	1.62					
F1 with F2[b]			0.88	0.55	0.60	0.55	0.49
Q1 with Q4			**0.78**	**0.74**	**0.46**	**0.20**	**−0.08**
Mean F1[b]			0.00[a]	0.56	0.22	0.46	0.45
Mean F2[b]			0.00[a]	0.34	−0.01	0.67	0.64
Thresholds	Q4. Cigarettes smoked daily$1	0.64					
	Q4. Cigarettes smoked daily$2	1.99					
	Q4. Cigarettes smoked daily$3[b]	2.70					
	Q1. Time until first cigarette$1	0.27					
	Q1. Time until first cigarette$2	1.06					
	Q1. Time until first cigarette$3[b]	2.67					
	Q5. Difficult to keep from smoking in places where it is not allowed?$1	1.92					
	Q2. Hate to give up your first cigarette of the day $1	1.12					
	Q3. Smoke more frequently during the first hours after waking$1	1.74					
	Q6. Do you smoke if you are so ill that you are in bed? $1	1.70					
Variance F1[b]			1.00[a]	0.66	0.64	0.70	0.56
Variance F2[b]			1.00[a]	0.66	0.72	0.59	0.51
Residual variances	Q1. Time until first cigarette	1.00[a]					
	Q2. Hate to give up your first cigarette of the day	1.00[a]					
	Q3. Smoke more frequently during the first hours after waking?	1.00[a]					
	Q4. Cigarettes smoked daily		**1.00[a]**	**2.68**	**2.45**	**0.77**	**0.60**
	Q5. Difficult to keep from smoking in places where it is not allowed?	1.00[a]					
	Q6. Do you smoke if you are so ill that you are in bed most of the day?	1.00[a]					

Note: Values printed in bold indicate DIF; [a] constrained parameter; [b] parameter freely estimated in agreement with model specification.

model fit (RMSEA = 0.052, CFI = 0.984). Finally, the strict invariance model did not provide a good fit (RMSEA = 0.086, CFI = 0.935). We followed the same strategy as the metric invariance model and modelled a residual correlation between the items "Cigarettes smoked daily" and "Time until first cigarette" which was not constrained to be equal among the five ethnic groups. The fit of this model was still not adequate (RMSEA = 0.079; CFI = 0.948). Modification indices suggested that the residual variances of the item "Cigarettes smoked daily" varied across ethnic groups. Releasing the constraint of identical item variances for this item resulted in good model fit (RMSEA = 0.055, CFI = 0.976). Parameter estimates of this final model are provided in Table 3. The final model includes two factors (F1 loads on Questions 1,

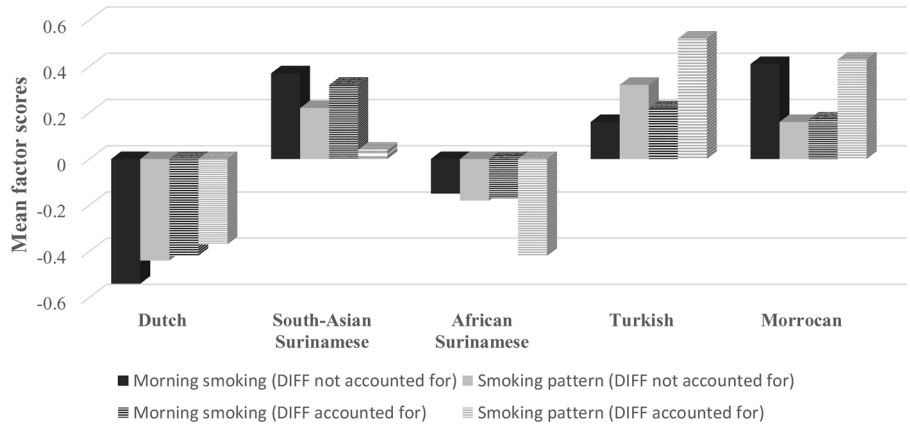

Fig. 1. Mean factor scores on "morning smoking" and "smoking pattern" across ethnic groups. Scores are corrected for age and sex. Scores are estimated in models that either do or do not account for differential item functioning.

2, and 3; F2 loads on Questions 1, 4, 5, and 6) which are allowed to be correlated. Factor loadings and item thresholds are invariant across ethnic groups. A residual correlation between Q1 and Q4 is modelled, this correlation varies across ethnic groups. In addition, the residual variances of Q4 are allowed to differ across ethnic groups.

3.5. Differences in "morning smoking" and "smoking pattern" across ethnic groups

We compared the factor scores obtained from a model that was unadjusted and a model that was adjusted for DIF while controlling for age and sex (see Fig. 1). All ethnic minority groups obtained significantly higher scores on the factors "morning smoking" and "smoking pattern" compared to the Dutch group (all $p < 0.001$) when DIF was not accounted for. After accounting for DIF, the African Surinamese group obtained slightly lower scores on the factor "smoking pattern" compared to the Dutch group, although the difference was not significant after correction for multiple testing ($p = 0.043$). South-Asian Surinamese and Moroccans showed particularly high scores on morning smoking while Turkish obtained the highest score on smoking patterns. Controlling for DIF influenced the differences in factor scores observed across ethnic groups with some differences decreasing after appropriate accounting for DIF (e.g., in the South-Asian Surinamese groups) while other differences increased (e.g., in the Turkish group).

4. Discussion

We explored differences in two different components of ND as assessed by the FTND across five ethnic groups. We observed that the factor structure of the FTND was not measurement invariant across ethnic groups implicating significant differential item functioning (DIF). Nevertheless, smokers from three out of four (South-Asian Surinamese, Turkish, and Moroccan) ethnic minority groups obtained significantly higher ND scores compared to the Dutch origin group, even when DIF was accounted for.

The observation that the two factors "Morning Smoking" and "Smoking Pattern" contributed to variation in FTND items across all ethnic groups implies that ND is a multi-factorial trait. Several assumptions of measurement invariance were violated. The residual correlation among the items "Time until first cigarette" and "Cigarettes per day" were significantly different across groups with a high correlation observed in the Dutch ethnic origin group while the correlations in the African Surinamese, Turkish, and Moroccan groups were much lower, implying that these two different aspects of smoking do not assess the same underlying vulnerability in these groups. Furthermore, the residual variances of the item "Cigarettes per day" were significantly different across ethnic groups. The item was assessed with relatively high accuracy in the Moroccan group and low accuracy in the South-Asian and African Surinamese groups. Overall, the finding of significant DIF in the factor structure of the FTND across ethnic groups is in agreement with earlier findings in African-American adolescents (Schroeder and Moolchan, 2007), and European and African-American current and former adult smokers (Johnson et al., 2008). The item "Cigarettes per day" showed DIF in all three studies, suggesting that this item cannot be compared directly across ethnic groups.

Apparently, the scores obtained across groups with different ethnicity may be easily misinterpreted. Since the items that show DIF are key components of nicotine dependence, we would not recommend deleting them from the questionnaire when comparing scores across groups. We would suggest to explore the presence of DIF before comparing mean scores, and taking DIF into account as was done in the present study. To improve the classification and comparison of the degree of nicotine dependence across patients with different ethnicity, one might consider to extend the six-item FTND with questions which reflect certain aspects of nicotine dependence not addressed in the FTND. Examples are questions about tobacco smoking trajectories (onset of both initial and daily smoking, and the time interval from initial to daily smoking), intensity of smoking (number of inhalations per cigarette, estimated butt weight) and/or readiness to quit smoking. Indeed, such items seem relevant as African-American smokers responded to part of these items in a different way than non-African-American smokers (Burgess et al., 2014; Duncan et al., 2012; Rayens et al., 2013).

We also aimed to explore differences in mean levels of ND across smokers from different ethnic groups. We showed that mean FTND factor scores and FTND observed scores were significantly higher in South-Asian Surinamese, Turkish, and Moroccan origin participants, results which agree with Visser et al. (2017) who reported higher rates of ND in these groups. The current literature has mainly focused on differences in ND between Americans of African and European descent and the findings are somewhat inconsistent. On the one hand, African-Americans seem to have less severe smoking patterns: they start smoking later, have a longer transition time between smoking initiation and nicotine dependence, smoke fewer cigarettes per day, report lower nicotine dependence and have greater readiness to quit (Burgess et al., 2014; Duncan et al., 2012; Rayens et al., 2013). On the other hand, it has been suggested that without significantly higher FTND score or shorter time to first cigarette of the day, smokers of African origin could have higher rates of tobacco biomarkers (nicotine metabolites and carcinogens), reflecting that they tend to smoke at higher intensity (St Helen et al., 2013). In our study, African Surinamese smoked on average fewer cigarettes per day compared to the Dutch while they were also the minority group that scored most similar to the Dutch ethnic group on "morning smoking" and "smoking pattern" factors.

The observed ethnic differences may be related to differences in

genetic background across ethnic groups (Benowitz et al., 2006). A recent Genome-Wide Association study of nicotine metabolism conducted in African-American smokers revealed that genetic variants at chromosome 19 impact the activity of *CYP2A6*, the major nicotine-inactivating enzyme (Chenoweth et al., 2018). Genetic factors explained ~20% of the variability in nicotine metabolite rate. Since these genetic variants occur at different frequencies in the African vs. European populations, they may contribute to inter-ethnic variability in nicotine metabolism and smoking behaviours. In addition to genetic risk factors, psychological factors (e.g., neuroticism, extroversion), and sociological factors may be responsible for the observed differences in ND (Webb Hooper and Kolar, 2015).

We observed high rates of ND among South-Asian Surinamese, Turkish, and Moroccan ethnic minority groups. The FTND score has a strong correlation with withdrawal symptoms and relapse to smoking because of withdrawal symptoms (DiFranza et al., 2012; Fagerström et al., 2012; Moolchan et al., 2002; Rios-Bedoya et al., 2008), and subjects from minority groups may therefore find it more difficult to quit smoking. Considering the relatively high smoking and ND rate in ethnic minority groups, smoking cessation programs should be especially focused on these vulnerable groups, and have already shown promising results at least on short term endpoints (Webb Hooper et al., 2017). Furthermore, the risk of disease and mortality (e.g., lung cancer) due to smoking was found to be higher in African-American compared to white smokers (Chenoweth et al., 2018) possibly due to differences in nicotine metabolism. The relationship between smoking and disease risk has not yet been investigated in the other ethnic minority groups and should be the focus of future research.

The findings of this study should be interpreted in the context of specific strengths and limitations. The strengths of this study are the inclusion of large numbers of participants across five ethnic groups, who were randomly drawn from the municipal register. We evaluated and accounted for the presence of DIF when comparing mean levels of ND across ethnic groups. Nevertheless, there are also some limitations. First, we did not have access to any biomarkers of nicotine levels or nicotine metabolism and we can therefore not compare smoking intensities across ethnic groups. Although the number of cigarettes per day (CPD) is used as a proxy for nicotine intake, it is possible that ethnic groups show variation in the relation between CPD and nicotine intake per cigarette. Second, our response rate was relatively low, possibly resulting in selection bias, e.g., non-responders to our study might be in particular individuals with the lowest proficiency of the Dutch language. However, we were able to include large numbers of each ethnic group in which all social-economic levels are represented, and non-response analyses showed that socio-economic differences between participants and non-participants were very small (Snijder et al., 2017).

In conclusion, the factor structure of the FTND is not measurement invariant across ethnic groups in this population-based sample from the Netherlands. Although accounting for DIF affected the comparison of nicotine dependence scores, three out of four ethnic minority groups showed significantly higher levels of nicotine dependence than the Dutch, while only African Surinamese were similar to subjects of Dutch origin. Genetic as well as environmental factors may account for observed differences. Future studies should explore the impact of differences in smoking rates and nicotine dependence on physical and mental health.

Role of the funding sources

The funding sources had no role in the design of this study and did not have any role during its execution, analyses, interpretation of the data, or decision to submit results.

Contributors

E.M. Derks performed analyses. J. van Amsterdam, F. Vorspan, and E.M. Derks wrote the first draft of the article. All authors edited the manuscript draft and have read and approved the final version of the manuscript.

Conflict of interest

No conflict declared.

Acknowledgements

The Academic Medical Center (AMC) of Amsterdam and the Public Health Service of Amsterdam (GGD Amsterdam) provided core financial support for HELIUS. The HELIUS study is also funded by research grants of the Dutch Heart Foundation (grant no. 2010T084), the Netherlands Organization for Health Research and Development (ZonMw; grant no. 200500003), the European Integration Fund (EIF; grant no. 2013EIF013) and the European Union (Seventh Framework Programme, FP-7; grant no. 278901). We are most grateful to the participants of the HELIUS study and the management team, research nurses, interviewers, research assistants and other staff who have taken part in gathering the data of this study.

References

Aspinall, P.J., Mitton, L., 2014. Smoking prevalence and the changing risk profiles in the UK ethnic and migrant minority populations: implications for stop smoking services. Public Health 128, 297–306.
Benowitz, N.L., Swan, G.E., Jacob, P., Lessov-Schlaggar, C.N., Tyndale, R.F., 2006. CYP2A6 genotype and the metabolism and disposition kinetics of nicotine. Clin. Pharmacol. Ther. 80, 457–467.
Bentler, P.M., 1990. Comparative fit indexes in structural models. Psychol. Bull. 107, 238–246.
Bollen, K., Long, J.S., 1993. Testing Structural Equation Models. Sage Publications, Newbury Park, CA.
Burgess, D.J., van Ryn, M., Noorbaloochi, S., Clothier, B., Taylor, B.C., Sherman, S., Joseph, A.M., Fu, S.S., 2014. Smoking cessation among African American and white smokers in the Veterans Affairs health care system. Am. J. Public Health 104 (Suppl. 4), S580–S587.
Chabrol, H., Niezborala, M., Chastan, E., Montastruc, J.L., Mullet, E., 2003. A study of the psychometric properties of the Fagestrom Test for Nicotine Dependence. Addict. Behav. 28, 1441–1445.
Chenoweth, M.J., Ware, J.J., Zhu, A.Z.X., Cole, C.B., Cox, L.S., Nollen, N., Ahluwalia, J.S., Benowitz, N.L., Schnoll, R.A., Hawk, L.W.J., Cinciripini, P.M., George, T.P., Lerman, C., Knight, J., Tyndale, R.F., 2018. Genome-wide association study of a nicotine metabolism biomarker in African American smokers: impact of chromosome 19 genetic influences. Addiction 113, 509–523.
Choi, J.S., Payne, T.J., Ma, J.Z., Li, M.D., 2017. Relationship between personality traits and nicotine dependence in male and female smokers of African-American and European-American samples. Front. Psychiatr. 8, 122.
DiFranza, J.R., Savageau, J.A., Wellman, R.J., 2012. A comparison of the autonomy over tobacco scale and the Fagerstrom test for nicotine dependence. Addict. Behav. 37, 856–861.
Duncan, A.E., Lessov-Schlaggar, C.N., Sartor, C.E., Bucholz, K.K., 2012. Differences in time to onset of smoking and nicotine dependence by race/ethnicity in a Midwestern sample of adolescents and young adults from a high risk family study. Drug Alcohol Depend. 125, 140–145.
Fagerstrom, K.O., Heatherton, T.F., Kozlowski, L.T., 1992. Nicotine addiction and its assessment. Ear Nose Throat J. 69, 763–767.
Fagerström, K., 2012. Determinants of tobacco use and renaming the FTND to the Fagerstrom test for cigarette dependence. Nicotine Tob. Res. 14, 75–78.
Fagerström, K., Furberg, H., 2008. A comparison of the Fagerstrom Test for Nicotine Dependence and smoking prevalence across countries. Addiction 103, 841–845.
Fagerström, K., Russ, C., Yu, C.R., Yunis, C., Foulds, J., 2012. The Fagerstrom Test for Nicotine Dependence as a predictor of smoking abstinence: a pooled analysis of varenicline clinical trial data. Nicotine Tob. Res. 14, 1467–1473.
Haddock, C.K., Lando, H., Klesges, R.C., Talcott, G.W., Renaud, E.A., 1999. A study of the psychometric and predictive properties of the Fagerstrom Test for Nicotine Dependence in a population of young smokers. Nicotine. Tob. Res 1, 59–66.
Heatherton, T.F., Kozlowski, L.T., Frecker, R.C., Fagerstrom, K.O., 1991. The Fagerstrom test for nicotine dependence: a revision of the Fagerstrom tolerance questionnaire. Br. J. Addict. 86, 1119–1127.
Horn, J.L., McArdle, J.J., 1992. A practical and theoretical guide to measurement invariance in aging research. Exp. Aging Res. 18, 117–144.
Hu, L.T., Bentler, P.M., 1995. Evaluating model fit. In: Hoyle, R.H. (Ed.), Structural Equation Modeling: Concepts, Issues, and Applications. Sage, London, pp. 76–99.
IBM, 2016. Statistics, IBM SPSS. "Version 22.". Armonk, IBM Corp.
Jhanjee, S., Sethi, H., 2010. The Fagerstrom test for nicotine dependence in an Indian sample of daily smokers with poly drug use. Nicotine. Tob. Res. 12, 1162–1166.

John, U., Meyer, C., Rumpf, H.J., Hapke, U., 2003. Probabilities of alcohol high-risk drinking, abuse or dependence estimated on grounds of tobacco smoking and nicotine dependence. Addiction 98, 805–814.
Johnson, E.O., Morgan-Lopez, A.A., Breslau, N., Hatsukami, D.K., Bierut, L.J., 2008. Test of measurement invariance of the FTND across demographic groups: assessment, effect size, and prediction of cessation. Drug Alcohol Depend. 93, 260–270.
Moolchan, E.T., Radzius, A., Epstein, D.H., Uhl, G., Gorelick, D.A., Cadet, J.L., Henningfield, J.E., 2002. The Fagerstrom test for nicotine dependence and the diagnostic interview schedule: do they diagnose the same smokers? Addict. Behav. 27, 101–113.
Muthén, B.O., Asparouhov, T., 2002. Latent Variable Analysis With Categorical Outcomes: Multiple-group and Growth Modeling in Mplus. Mplus Web Notes: No. 4. Muthén and Muthén, Los Angeles. https://www.statmodel.com/download/webnotes/CatMGLong.pdf.
Muthén, L.K., Muthén, B.O., 2010. Mplus User's Guide, sixth ed. Muthén and Muthén, Los Angeles. https://www.statmodel.com/download/usersguide/Mplus%20Users%20Guide%20v6.pdf.
Ng, M., Freeman, M.K., Fleming, T.D., Robinson, M., Dwyer-Lindgren, L., Thomson, B., Wollum, A., Sanman, E., Wulf, S., Lopez, A.D., Murray, C.J.L., Gakidou, E., 2014. Smoking prevalence and cigarette consumption in 187 countries, 1980-2012. JAMA 311, 183–192.
Nierkens, V., de Vries, H., Stronks, K., 2006. Smoking in immigrants: do socioeconomic gradients follow the pattern expected from the tobacco epidemic? Tob. Control 15, 385–391.
Payne, T.J., Smith, P.O., McCracken, L.M., McSherry, W.C., Antony, M.M., 1994. Assessing nicotine dependence: a comparison of the Fagerstrom Tolerance Questionnaire (FTQ) with the Fagerstrom Test for Nicotine Dependence (FTND) in a clinical sample. Addict. Behav. 19, 307–317.
Radzius, A., Gallo, J.J., Epstein, D.H., Gorelick, D.A., Cadet, J.L., Uhl, G.E., Moolchan, E.T., 2003. A factor analysis of the Fagerstrom Test for Nicotine Dependence (FTND). Nicotine. Tob. Res. 5, 40–255.
Rayens, M.K., Hahn, E.J., Fernander, A., Okoli, C.T.C., 2013. Racially classified social group differences in cigarette smoking, nicotine dependence, and readiness to quit. J. Addict. Nurs. 24, 71–81.
Richardson, C.G., Ratner, P.A., 2005. A confirmatory factor analysis of the Fagerstrom Test for Nicotine Dependence. Addict. Behav. 30, 697–709.
Rios-Bedoya, C.F., Snedecor, S.M., Pomerleau, C.S., Pomerleau, O.F., 2008. Association of withdrawal features with nicotine dependence as measured by the Fagerstrom Test for Nicotine Dependence (FTND). Addict. Behav. 33, 1086–1089.
Rutkowski, L., Svetina, D., 2018. Measurement invariance in international surveys: categorical indicators and fit measure performance. Appl. Measurement Educ. 30, 39–51.
Schermelleh-Engell, K., Moosbrugger, H., Müller, H., 2003. Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. Methods. Psychol. Res. 8, 23–74.
Schroeder, J.R., Moolchan, E.T., 2007. Ethnic differences among adolescents seeking smoking cessation treatment: a structural analysis of responses on the Fagerstrom Test for Nicotine Dependence. Nicotine Tob. Res. 9, 137–145.
Snijder, M.B., Galenkamp, H., Prins, M., Derks, E.M., Peter, R.J., Zwinderman, A.H., Stronks, K., 2017. Cohort profile: the healthy life in an Urban Setting (HELIUS) study. BMJ Open 7. https://doi.org/10.1136/bmjopen-2017-017873.
St Helen, G., Dempsey, D., Wilson, M., Jacob, P., Benowitz, N.L., 2013. Racial differences in the relationship between tobacco dependence and nicotine and carcinogen exposure. Addiction 108, 607–617.
Steinberg, M.L., Williams, J.M., Steinberg, H.R., Krejci, J.A., Ziedonis, D.M., 2005. Applicability of the Fagerstrom Test for Nicotine Dependence in smokers with schizophrenia. Addict. Behav. 30, 49–59.
Stronks, K., Kulu-Glasgow, I., Agyemang, C., 2009. The utility of' country of birth' for the classification of ethnic groups in health research: the Dutch experience. Ethn. Health 14, 255–269.
Stronks, K., Snijder, M.B., Peters, R.J.G., Prins, M., Schene, A.H., Zwinderman, A.H., 2013. Unravelling the impact of ethnicity on health in Europe: the HELIUS study. BMC Public Health 13, 402.
Sullivan, P.F., Kendler, K.S., 1999. The genetic epidemiology of smoking. Nicotine Tob. Res. 1 (Suppl. 2), S51–S57.
Visser, M.J., Ikram, U.Z., Derks, E.M., Snijder, M.B., Kunst, A.E., 2017. Perceived ethnic discrimination in relation to smoking and alcohol consumption in ethnic minority groups in the Netherlands: the HELIUS study. Int. J. Public Health 62, 879–887.
Webb Hooper, M., Antoni, M.H., Okuyemi, K., Dietz, N.A., Resnicow, K., 2017. Randomized controlled trial of group-based culturally specific cognitive behavioral therapy among African American smokers. Nicotine Tob. Res. 19, 333–341.
Webb Hooper, M., Kolar, S.K., 2015. Distress, race/ethnicity and smoking cessation in treatment-seekers: implications for disparity elimination. Addiction 110, 1495–1504.