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Abstract

It is still not clear how chronotype influences caffeine consumption (CC) and caffeine use disorder (CUD). The aim of the study was to investigate the relationship between chronotype, CC, CUD, and wellbeing. Participants of an online survey in Hungary (N = 2259) answered the CUD Questionnaire, Morningness-Eveningness Questionnaire and the WHO-5 Well-Being Index. Morningness positively associated with tea consumption, and negatively with cola and energy drink consumption. Severe CUD was more common among evening-type participants. Two significant mediations were found in the path model: Morningness→Tea consumption→Wellbeing and Eveningness→Energy drink consumption →CUD. It is concluded that CUD like other substance use disorders is associated with eveningness. The results indicate that the carrier beverages of the chemical compound of caffeine should be examined separately. Energy drink use can be accompanied by more unfavorable consequences, especially for evening-types, while tea consumption, which was associated with morningness, had more favorable consequences, like higher wellbeing.

Keywords: caffeine; caffeine use disorder; chronotype; morningness; wellbeing

Introduction

Chronotype is the preference of an individual regarding the timing of sleep and activity which is regulated by the circadian clock (Wittmann, Dinich, Merrow, & Roenneberg, 2006). Individuals who are located on the more extreme position toward morningness ("early birds") prefer to go to bed early in the evening and perform activities better in the morning hours, whereas those who are characterized as evening-type individuals ("night owls") prefer to rise later in the morning and go to bed later and perform better in the late afternoon or evening. More specifically, 2 to 12 hours of phase lag can be observed between the two extremes of the chronotype dimension, and there are differences in the physical functioning and mental health characteristics between individuals with different chronotypes (Adan et al., 2012).

Several studies have examined the relationship of chronotype and specific health-impairing behaviors. For adolescents, higher level of eveningness predicts higher lifetime alcohol use, greater experimenting with smoking cigarettes, higher probability of smoking cigarettes daily and nondaily, and greater physical inactivity (Urbán, Magyaródi, & Rigó, 2011), and is also associated with the tendency to (i) consume caffeinated drinks and fast food (Fleig & Randler, 2009), (ii) eat more unhealthy snacks, (iii) eat less fruit and vegetables, and (iv) engage in night-time caffeine consumption (Arora & Taheri, 2015).

The association between health-impairing behaviors – including substance use as well as substance use disorders – and chronotype has also been examined in adult populations. According to one comprehensive review (Fabbian et al., 2016) individuals with higher eveningness have more unhealthy eating habits and show less physical activity. Haraszti et al. (2014) found that eveningness was associated with greater stress, less frequent physical activity, and less healthy diet among Hungarian working women, and that physical activity weakened the strength of the association between eveningness and lower wellbeing. Additionally, Kervran et al. (2015) found that morningness-eveningness is associated with specific addiction patterns,

namely that higher eveningness was associated with behavioral addictions, cannabis addiction, and poly-problematic addiction (i.e., addiction to more than one substance and/or behavior).

Results of several studies suggest that compared to morning-type individuals, evening-type individuals consume more alcohol and smoke more cigarettes (Ishihara et al., 1985; Randler, 2008; Tran et al., 2014; Whittier et al., 2014) and have a higher caffeine intake (Adan, 1994; Ishihara et al., 1985; Mitchell & Redman, 1993; Tran et al., 2014; Zhang et al., 2018). Penolazzi et al. (2012) found that the timing of caffeine consumption is also important, and reported that morning-type individuals consume more caffeine in the morning and evening-type individuals consume more caffeine in the evening. However, other studies have found that evening chronotype is not associated with the consumption of caffeinated beverages in the morning or in the evening (Wilson, 1990), nor after adjusting for age, sex, cigarette smoking, body mass index, and physical activity (Whittier et al., 2014).

Beyond mere caffeine consumption, it is also worth examining the specific type of caffeinated beverage. Results on the consumption of coffee and tea are somewhat contradictory. Adan (1994) found that evening-type individuals consume more coffee and less tea than morning-type individuals. However, in another study (Wittmann et al., 2006), late chronotypes were less likely to consume coffee than early chronotypes, while there was no correlation between chronotype and tea consumption. Prat and Adan (2011) found no difference between chronotype groups regarding coffee and tea consumption. In a study with Thai college students (Tran et al., 2014), compared to non-caffeine consumers, the odds of being an evening-type individual were 1.95-fold higher for coffee consumers and 2.31-fold higher for tea consumers. In relation to the consumption of cola, soft drinks, and energy drinks, such consumption is more frequent among later chronotypes (Adan, 1994; Prat & Adan, 2011; Tran et al., 2014; Wittmann et al., 2006) except for one study of Peruvian university students (Whittier et al., 2014).

The association of eveningness and the consumption of stimulant substances is hypothesized to be a consequence of social jetlag, namely the discrepancy between social and biological timing (Wittmann et al., 2006). Therefore, in order to cope with social demands and daytime sleepiness, evening-type individuals are probably more likely to use stimulants, (e.g., caffeine). However, caffeine can cause sleep disturbances (Roehrs & Roth, 2008) and is associated with wake after sleep onset (WASO) in morning-type individuals, but not in evening-type individuals. This is a likely further explanation of the preference for caffeinated beverages among evening-type individuals (Nova, Hernandez, Ptolemy, & Zeitzer, 2012). On the other hand, evening-typed Canadian university students tended to misuse energy drinks (i.e., increased tolerance, inability to stop, and negative consequences) to a greater extent than morning types (Ianni & Lafreniere, 2014).

It should also be noted that when examining the association of chronotype and mental health characteristics, substance use should be considered as a mediator. Wittmann et al. (2010) found that cigarette smoking and alcohol consumption mediated the relationship of chronotype and specific aspects of psychological wellbeing. More specifically, there was no direct association between chronotype and wellbeing, although those with higher eveningness and who also smoked cigarettes and drank alcoholic beverages had more sleep problems and were more depressed than those who did not smoke or drink.

According to Adan and et al. (2012), chronotype can be influenced by gender and age, therefore, these variables should be taken into consideration. Although evidence suggests that evening-type is more common among men (Adan et al., 2012; Adan & Natale, 2002; Danielsson, Sakarya, & Jansson-Fröjmark, 2019; Randler, 2007), several studies have reported no gender differences (Adan & Almirall, 1991; Prat & Adan, 2011). Females with evening-oriented preference are more likely to face negative health consequences which are usually associated with the evening chronotype (Fabbian et al., 2016; López-Soto et al., 2019). In addition to chronotype, gender can also affect the perceived effects of caffeine because a lower

dose of caffeine induces greater alertness effects in men compared to women (Adan, Prat, Fabbri, & Sànchez-Turet, 2008). For age, there is a relatively clear and well-observed association that higher age is associated with higher morningness (Adan & Almirall, 1991; Adan et al., 2012; Fabbian et al., 2016).

The aim of the present study was to investigate the complex relationship between morningness/eveningness, caffeine consumption, caffeine use disorder, and wellbeing. It was hypothesized that (i) higher degree of eveningness would be associated with higher total caffeine consumption, and (ii) lower wellbeing (Wittmann et al., 2006). Furthermore, based on the results of Wittmann et al. (2010) it was also hypothesized that (iii) caffeine use could be a mediator between chronotype and wellbeing. It was also hypothesized that (iv) higher eveningness would predict a greater amount of CUD symptoms, while (v) CUD would have a negative association with wellbeing. Additionally, another aim was to examine the role of different caffeinated beverages (i.e., coffee, tea, cola, and energy drinks) separately, because it was hypothesized that (vi) eveningness would be associated with energy drink and cola consumption, and probably with coffee and tea consumption as well. However, the strength of the relationship is possibly different in the case of each caffeinated beverage.

Material and methods

Sample and procedures

Participants were surveyed concerning their caffeine consumption habits, chronotype, and wellbeing in an online questionnaire utilizing convenience sampling. The questionnaire was published on a Hungarian news website (www.444.hu) and was available for two months in 2015. Adults (< 18 years) who consumed caffeine at least once in the last year were invited to participate. Informed consent was placed on the first page of the questionnaire and participants needed to indicate that they had read the consent and agreed with it in order to continue with the questionnaire. Further details of the same sample [N = 2259, 70.5% male, M_{age} = 33.97

years SD_{age} = 9.3] and procedure have been published elsewhere (citation is masked for blind review purposes). The study was approved by the research team's university's ethics committee.

Measures

Caffeine consumption

The consumption of coffee (brewed and instant), tea (black and green), energy drink, cola, and caffeine pill was assessed on an eight-point scale (0 = never, 1 = less than weekly, 2 = several times in a week, 3 = one portion/day, 4 = two portions/day, 5 = three portions/day, 6 = four portions/day, 7 = five or more portions/day). The caffeine content of the products was estimated as follows: one portion of brewed coffee = 100 mg, one portion of instant coffee = 60 mg, one portion of tea = 45 mg, one portion of energy drink = 75 mg, one portion of cola = 30 mg, and one caffeine pill = 100 mg. Total daily consumption of those who did not indicate daily consumption of any of the caffeinated products was calculated as zero. Coffee, tea, energy drink and cola consumption were transformed to dummy variables (no daily consumption/daily consumption) for the path analysis.

Caffeine use disorder

The 10-item Caffeine Use Disorder Questionnaire (CUDQ) comprises the proposed DSM-5 criteria of caffeine use disorder. Based on an IRT analysis (Ágoston, Urbán, Richman, & Demetrovics, 2018), the items of the unidimensional CUDQ have sufficient discriminative value and cover the latent continuum of CUD from mild to severe. The internal consistency of CUDQ was acceptable in the present study (Cronbach's $\alpha = 0.71$). Three CUD-groups were also created based on the suggestions of DSM-5 regarding general substance use disorder severity (American Psychiatric Association, 2013): no CUD (less than two symptoms), mild-moderate CUD (two to five symptoms), and severe CUD (more than six symptoms).

Morningness-eveningness

For the assessment of chronotype, the Hungarian version of the reduced Horne and Östberg Morningness-Eveningness Questionnaire (rMEQ) (Adan & Almirall, 1991) was used. The five-item scale assesses comfortable rising time, morning freshness, retiring time, subjective peak time, and self-evaluation of chronotype. Higher scores on the scale indicate higher degree of morningness. Chronotype-groups were defined on the basis of previous studies (Adan & Almirall, 1991; Chelminski, Petros, Plaud, & Ferraro, 2000; Danielsson et al., 2019): evening-type (< 12 points on rMEQ), neither-type (12-17 points), and morning-type (> 17 points). Cronbach's α of the German version was 0.72 (Randler, 2013). The internal consistency of rMEQ was acceptable in the present study (Cronbach's α = 0.75).

Wellbeing

The WHO-5 Well-Being Index (WHO-5) (World Health Organization, 1998) was used to assess wellbeing and comprises five positively-worded items with four response categories (from 0 to 3). Higher scores on the scale indicate higher wellbeing. The internal consistency of WHO-5 in a representative Hungarian sample was good (Cronbach's α = 0.85) (Susánszky, Konkoly Thege, Stauder, & Kopp, 2006). The internal consistency of WHO-5 was also good in the present study (Cronbach's α = 0.80).

Statistical analysis

Descriptive statistics, Pearson correlations, chi-square tests, Kruskal-Wallis test, ANOVAs and Cronbach's alphas were performed with SPSS 22 (IBM Corp., 2011), and the path analysis was performed with MPLUS 6.0 (Muthén & Muthén, 1998-2011). Morningness-eveningness has been used as a categorical variable in several studies (e. g. Adan, 1994; Arora & Taheri, 2015; Ishihara et al., 1985; Mitchell & Redman, 1993; Nova et al., 2012; Tran et al., 2014; Whittier et al., 2014; Wilson, 1990) while other studies have used it as a continuum (Fleig & Randler, 2009; Vedaa, Bjorvatn, Magerøy, Thun, & Pallesen, 2013; Wittmann et al., 2006; Wittmann et al., 2010) or used both approach (Kervran et al., 2015; Urbán et al., 2011). In the present study,

both methods were used. First, chronotype-groups were compared. ANOVA or the Welch test were used for continuous variables (age and total daily caffeine consumption) with Games-Howell post-hoc tests, Kruskal-Wallis tests were used for ordinal variables (coffee, tea, energy drink and cola consumption) with Mann-Whitney U-tests for post hoc comparisons with Bonferroni corrected *p*-values, and chi-square post-hoc tests for categorical variables (gender and CUD) with adjusted residuals and Bonferroni corrected *p*-values for post-hoc comparisons. The correlation of rMEQ-score, WHO-5-score, CUD-score, total daily caffeine consumption, and the consumption of each caffeinated beverages was examined as well.

In the path analysis, MEQ score was used as an independent continuous variable, wellbeing as continuous dependent variable, and caffeine use disorder as a continuous mediator, while the daily use of coffee, tea, cola, and energy drinks were used as binary mediator variables similar to other studies (Tran et al., 2014; Whittier et al., 2014). Using binary variables – compared to zero-inflated ordinal variables – allowed for easier interpretation of the results. The path analysis was computed using a probit regression method with weighted least square parameter estimator (WLSMV) and delta parameterization.

Model fit was investigated by examining χ^2-test statistic, the Comparative Fit Index (CFI) (Bentler, 1990), the Tucker–Lewis Index (TLI) (Tucker & Lewis, 1973), the Root Mean Square Error of Approximation (RMSEA) (Steiger, 1990), and its 90% confidence interval (MacCallum, Browne, & Sugawara, 1996). CFI and TLI were considered acceptable above 0.90 and excellent above 0.95, while RMSEA below 0.08 indicated an acceptable fit and below 0.05 an excellent fit (Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 1999).

Results

Descriptive statistics

Coffee was the most popular caffeinated beverage among participants with 79% consuming it daily, followed by tea (17.1%), cola (6.8%), and energy drinks (3.9%). The average daily

caffeine consumption was 246.2 mg (SD = 140.7). Approximately one-third of the participants were classified as evening-type (31.1%), 17.6% were classified as morning-type, and the remaining 51.4% were neither type, proportions which are quite similar to previous findings (Adan & Almirall, 1991; Adan et al., 2012; Adan & Natale, 2002; Danielsson et al., 2019). A quarter of the participants had no CUD (24.3%), 62.1 had mild-moderate CUD, and 13.6% had severe CUD.

Comparison of the chronotype-groups regarding gender, age, caffeine consumption and CUD

As shown in Table 1, there was no gender difference in circadian typology, but age was significantly different in the three groups. Therefore, age was included as a covariate in the second ANOVA, which showed a significant between-group difference regarding daily caffeine consumption. The post-hoc test indicated that caffeine consumption was higher in the evening-type group compared to the neither-type group. The effect size was low in both cases. Morning-types had higher tea consumption and evening-types had higher energy drink consumption than the other two groups, while cola consumption was different in every group. There was also a significant difference in CUD status between the three groups: evening-type combined with severe CUD occurred significantly more than expected, while evening-type combined with no CUD occurred significantly less than expected.

Table 2

Correlation of the variables

The correlation matrix of the variables is presented in Table 1. One of the most important findings of the correlational analyses is that total daily caffeine consumption was not correlated with morningness or wellbeing. However, the consumption of three caffeinated beverages (tea, energy drinks, and cola) was associated with both chronotype and wellbeing, and the

consumption of all the four caffeinated beverages was correlated with caffeine use disorder (CUD).

<Insert Table 2 here>

Path analysis

Because total daily caffeine consumption did not correlate with moringness, the present authors decided to use the caffeine consumption variables (coffee, tea, energy drinks, cola) separately instead of a composite caffeine consumption variable. The path analysis therefore included morningness, the daily consumption of coffee, tea, cola, and energy drinks, CUD, and wellbeing and resulted a saturated model. The unstandardized and standardized regression coefficients of the path analysis and the relationship of the variables are depicted in Figure 1.

<Insert Figure 1 here>

Two relevant and significant indirect paths were found: (i) *morningness → tea consumption → wellbeing* (B = 0.007, S.E. = 0.003, p = 0.038, β = 0.009), where higher morningness predicted tea consumption, and tea consumption predicted higher wellbeing, and (ii) ***eveningness*** *→ energy drink consumption → CUD* (B = -0.050, S.E. = 0.014, $p < 0.001$, β = -0.098), where higher eveningness predicted energy drink consumption, and energy drink consumption predicted higher CUD. All other relevant indirect pathways were non-significant ($p > .05$).

Discussion

As hypothesized, the analyses verified the positive association of eveningness with energy drink and cola consumption, but not with coffee consumption. Tea consumption had a positive relationship with morningness, similar to the study by Adan (1994). The present results indicate that using types of caffeinated beverages as separate variables was more advantageous than using the total caffeine consumption as a composite variable because some effects with different

directions appear to cancel each other out (e.g., tea vs. cola and energy drinks). As expected, age was positively associated with morningness. The indings also highlighted that age was a possible confounding in the relationship of chronotype and total caffeine consumption, which should be taken into account in future studies. However, gender was not associated with chronotype, which is in line with the results of Adan and Almirall (1991) and Prat et al. (2011), but contradicts other findings (Adan et al., 2012; Adan & Natale, 2002; Danielsson et al., 2019; Randler, 2007). The lack of difference may have occurred because of the lower proportion of women in the present sample.

As expected, morningness had a high positive relationship with wellbeing (in other words higher eveningness was accompanied with lower wellbeing) in both analyses which may confirm the previous results regarding the lower wellbeing of evening-types (Adan et al., 2012; Fabbian et al., 2016). Based on the study of Wittman et al. (2010) it was hypothesized that decreased wellbeing in later chronotypes would be mediated by caffeine consumption but only tea comsumption was a significant mediator between chronotype and wellbeing, and that was in a different direction (i.e., morning-type individuals who consumed tea were characterized as having a higher degree of wellbeing). Humanity has a long history of tea consumption (e.g., tea rituals in China) and suggests that tea consumption may have other functions in addition to enhancing alertness. It is also worth noting that tea has lower caffeine content than coffee and energy drinks, and tea consumers have lower motives for mood enhancement and alertness than those who consume coffee or have mixed caffeine consumption habits – at least according to a previous Hungarian study (Ágoston, Urbán, Király, et al., 2018). Consequently, the association of tea consumption and wellbeing can be therefore explained by variables other than the motive of enhancing alertness.

Although morningness had a negative correlation with caffeine use disorder (CUD) in the correlation matrix, and severe CUD was more common among evening-type individuals according to chi-square analysis, there was only an indirect association – with the mediation of

energy drink use – between these two variables in the path analysis. These results suggest that evening-types may consume caffeinated products (such as energy drinks) to compensate their 'social jetlag', but end up worsening their situation because they are more likely to experience the negative consequences of caffeine use (e.g. symptoms of CUD and lower general wellbeing). Consequently, it is worth putting greater emphasis on energy drink consumption in future studies focusing on problematic caffeine use. Energy drink use may can also lead to other negative consequences including insomnia, nervousness, headache, tachycardia, seizures, and manic episodes (Clauson, Shields, McQueen, & Persad, 2008). Despite these possible negative consequences, energy drink consumption increased in recent years (Breda et al., 2014) and 8.9% of Hungarian adolescents consume it daily (Németh & Költő, 2014). Aggressive advertisements promote the psychoactive, performance-enhancing effects of energy drinks and appear to glorify drug use (Reissig, Strain, & Griffiths, 2009) which may overshadow other possible motives. The results of the present study indicate that evening-type individuals can be especially affected by the negative consequences of energy drink consumption.

Although coffee consumption was also associated with CUD, it did not play a mediating role between morningness and CUD. This indicates that coffee consumption can lead to experiencing the symptoms of addiction for both morning-type and evening-type individuals. An important question for future studies is why energy drink consumption can lead to negative consequences in evening-type individuals, while other caffeinated beverages do not (e.g., coffee)? The previously cited studies have also highlighted this contradiction. For instance, Nova et al. (2012) found that total daily caffeine consumption can affect evening-type individuals differently compared to morning-type individuals, whereas Ianni and Lafreniere (2014) – who focused not only on total caffeine consumption but also energy drink use – found that energy drink misuse was more common among evening-typed women. It is therefore possible that not only the type of the consumed caffeinated beverage matters when examining the relationship of morningness, CUD, and wellbeing, but also the timing of caffeine

consumption (Penolazzi et al., 2012), although this was not assessed in the present study. However, it appears that the effects of energy drink consumption are still visible (without knowing the timing of consumption) which (compared to other caffeinated beverages) suggests a stronger relationship between eveningness, energy drink consumption, and CUD.

It is also important to consider that both tea and coffee consumption have their cultural context and rituals, whereas energy are consumed without any social context in order to regulate arousal. Without any social and cultural control mechanisms, psychoactive substance use can easily develop into psychoactive substance abuse in many civilizations (Westermeyer, 2005). This is a possible explanation of the more problematic consequences of energy drink use, which have a shorter history of research compared to coffee or tea consumption.

The present study has some limitations. Although social and environmental factors influence morningness–eveningness, caffeine does not appear to have such an effect on the shift in chronotype (Vedaa et al., 2013). This implies that it is more likely that chronotype influences caffeine use than a reverse association between these two variables. Nevertheless, the cross-sectional design of the study only allows cautious conclusions regarding the possible causal relationship of chronotype, caffeine consumption, CUD, and wellbeing. Whittier et al. (2014) argue that caffeine can affect the circadian rhythm via daytime sleepiness, therefore, longitudinal studies are needed to delineate any causal direction between caffeine use and chronotype. Additionally, although the sample was large, generalizability of the results is limited by the non-representativeness of the sample. Further studies should investigate the effects of possible confounders such as school and work schedules, as well as the timing of caffeine consumption (Penolazzi et al., 2012) because these variables were not assessed in the present study. Despite of the aforementioned limitations, this is the first study to integrate chronotype, caffeine consumption (including different types of caffeinated beverages), caffeine use disorder, and wellbeing in a comprehensive model. The results regarding the more frequent occurrence of severe CUD among evening-type individuals also have clinical relevance. In the

further examination of CUD as a possible mental disorder, chronotype should be also considered as an influencing factor.

Disclosure of Interests

The authors report no conflict of interest.

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Table 1. The comparison of the chronotype-groups regarding gender, age, caffeine consumption, and Caffeine Use Disorder

Variable	Morning-type (N=389)	Neither-type (N=1138)	Evening-type (N=668)	χ^2 (df)/ F(df)
Age [mean (SD)]	38.42 (10.68)[a]	33.41 (8.78)[b]	32.35 (8.74)[c]	44.36 (2, 901.00)***
Gender, N of females (%)	121 (31.3)	345 (30.5)	178 (26.0)	5.10(2)
Total daily caffeine intake (mg) [mean (SE)][&]	236.69 (7.37)[a]	239.24 (4.20)[b]	257.92 (5.40)[ab]	4.42(2)*
Coffee				
Daily coffee consumer N (%)	303 (86.8)	902 (85.8)	547 (84.9)	0.68(3)
OR [95% CI] [&]	*Ref.*	1.21 [0.83-1.75]	1.12 [0.76-1.66]	
Tea				
Daily tea consumer N (%)	85 (23.7)	198 (18.5)	98 (14.8)	12.56(2)**
OR [95% CI] [&]	*Ref.*	0.78 [0.58-1.10]	0.63 [0.45-0.88]**	
Energy drink				
Daily energy drink consumer N (%)	8 (2.3)	30 (2.8)	44 (6.6)	19.18(2)***
OR [95% CI] [&]	*Ref.*	1.08 [0.48-2.39]	2.47 [1.13-5.38]*	
Cola				
Daily cola consumer N (%)	13 (3.7)	76 (7.0)	64 (9.7)	12.50(2)**
OR [95% CI] [&]	*Ref.*	2.14 [1.17-3.94]*	3.02 [1.62-5.63]**	
Caffeine Use Disorder				
Severe CUD *N (%)*	40 (11.0)	134 (12.3)	115 (17.5)	11.93(2)**
OR [95% CI] [&]	*Ref.*	1.13 [0.76-1.68]	1.61 [1.07-2.43]*	

Note: Means that have no superscript in common are significantly different from each other at p<.05.
[&]: Age was controlled in the analysis.
Ref.: Reference group.
*$p < .05$; **$p < .01$; ***$p < .001$.