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# Comparison of hair cortisol concentrations between self- and professionally-collected hair samples and the role of five-factor personality traits as potential moderators

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## ABSTRACT

Cortisol concentration of hair (HCC) is an established biomarker in stress research that can provide valuable retrospective information on subjects' long-term cortisol levels. Using a population-wide sample of in total  $N = 482$  participants this study aimed to examine whether there are differences in HCC when participants collect the required samples by themselves with the help of a partner in domestic settings compared to professionally collected hair strands in the lab. Potential confounding factors that may affect HCC and might obfuscate the outcomes were considered. The results suggest that the two compared sample collection methods did not significantly differ from each other in terms of HCC ( $p = .307$ ). A somewhat larger sample loss in the domestic setting was observed due to hair samples where HCC could not be determined (5.3 % vs. 1.8 % in the lab). Similarly, in a sample of  $N = 50$  using a within-subjects design (Sample 2) no significant HCC differences between collection methods occurred ( $p = .206$ ). In addition, potential moderating effects of personality traits of the Five-Factor-Model on the relationship between hair collection method and HCC were investigated. In Sample 1 personality data of the hair donor were available, while in Sample 2 personality data ( $n = 40$ ) were available for the hair donor and the hair sample collector. Interestingly, none of the Big Five traits significantly moderated the relationship between HCC and hair collection method (all  $p > .20$ ). Overall, these findings suggest that the self-collection of hair in domestic settings is a viable and economical method for measuring long-term cortisol concentrations in hair.

## 1. Introduction

Biomarkers, such as urinary, blood and salivary cortisol are well established in stress research (Kristenson et al., 2012). However, the essential problem that goes with measuring these biomarkers is that they cannot give retrospective information on a subject's cortisol level and therefore hardly provide information about long-term levels of stress by measuring just once (Doane et al., 2015). However, hair cortisol concentration (HCC) is considered suitable for such a purpose (Russell et al., 2012). This is due to the observation that human hair has an almost linear growth of averagely 1.06 cm per month (Agius and Kintz, 2010; LeBeau et al., 2011). In contrast to blood and urinary collection methods, hair sample collection is assumed to be well-tolerated by study participants (Stalder and Kirschbaum, 2012). A further potential

advantage of HCC in comparison to other collection methods is that situational factors do not result in acute changes of cortisol concentration such as induced by hypothalamus-pituitary-adrenal axis (HPA) activity through acute stressors (Grass et al., 2015; Skoluda et al., 2017). Additionally, hair sample storage is easy and accessible, whereas blood, urinary, and salivary samples require also refrigeration or freezing (Russell et al., 2012).

Of note, to increase efficiency it is expedient to request study participants to collect hair samples themselves with the assistance of a partner in domestic settings. Indeed, from a logistic and economic perspective, self-collection of hair samples in domestic settings offers great advantages over professional hair sample collection like larger sample sizes, lower time and monetary expenditure, faster recruiting and eased access to specific populations, such as to individuals that are

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unable to leave their home because of health reasons or because they live far from the lab. Exit restrictions, such as recently introduced in many countries due to the coronavirus crisis, may also prevent individuals to visit a lab. This inevitably brings up the question, whether these samples vary especially concerning cortisol concentrations from those which were taken by an experienced/trained sample collector and whether there are confounders or moderators influencing sample quality or the measured HCC, respectively.

While research on this important topic is sparse, the only systematic peer-reviewed study known to us so far was conducted by [Ouellet-Morin et al. \(2016\)](#). This study compared professionally and self-collected hair sampling methods based on cortisol concentrations, and also examined the role of selected confounders. The authors reported a strong association between both sample collection methods concerning HCC. However, these results were based on a small sample of  $N = 34$  only comprising 17–18 year-old individuals, which clearly highlights the necessity for further research. Proceeding from this, the present research primarily used a between-subjects design in a large population-based sample with hair cortisol data of  $N = 482$  individuals (Sample 1) to compare professionally and self-collected hair sample methods regarding differences in HCC. Potential confounding factors on HCC differences that may obfuscate the outcomes and interpretations of the results were considered such as the amount of hair washes, household size, BMI and ultraviolet ray exposure ([Braig et al., 2015](#); [Ouellet-Morin et al., 2016](#); [Stalder et al., 2012b](#)).

Beside this primary goal of our study, we were also interested to explore possible moderating effects of central personality traits on self- vs. professionally collected hair samples and its associated cortisol concentration. This question was addressed using Sample 1 where personality data of the hair sample donors were available as well as by means of a smaller sample where personality data of both hair donors and hair sample collectors were available. The question of personality as moderating factor of the relationship between collection method and HCC was raised for the following reasons: It is well known that personality traits crucially affect daily life by influencing thoughts, feelings, and actions in a relatively stable manner. Specifically, the potentially moderating personality traits neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness of the Five-Factor-Model (FFM) of personality ([Costa and McCrae, 1992](#)) were addressed in this study. Evidence linking these traits to the current question can be found in research regarding task/job performance and adherence behavior to (medical) instructions. Meta-analyses on self-reports and observer ratings of FFM traits revealed small to moderate positive associations of agreeableness and openness with task performance and voluntary task commitment ([Chiaburu et al., 2011](#); [Oh et al., 2011](#)). Further, individuals low in agreeableness also showed lower adherence behavior to medical instructions ([Emilsson et al., 2011](#)), while openness/intellect is linked with cognitive motivation or intellectual engagement (see [Enge et al., 2008](#); [Fleischhauer et al., 2010](#)) and might therefore be associated with a deeper elaboration and understanding of given hair collection instructions during self-collection of hair in domestic settings. Moreover, neuroticism was previously shown to influence task performance negatively if participants perceive the situation to be stressful ([Debusscher et al., 2016](#); [Dobson, 2000](#)), and positively if participants may want to avoid negative outcomes ([Mora et al., 2007](#); [Tamir, 2005](#)). Meta-analytic results demonstrate negative associations between neuroticism and task/job performance as well as with commitment behavior in organizational/work contexts, while extraversion showed positive associations ([Chiaburu et al., 2011](#); [Oh et al., 2011](#)). However, among the FFM dimensions, conscientiousness was shown to most strongly influence task performance ([Bakker et al., 2012](#); [Debusscher et al., 2017](#); [Hui-Hua and Schutte, 2015](#); [Oh et al., 2011](#)) and adherence behavior to instructions ([O' Cleirigh et al., 2007](#); [Stilley et al., 2004](#)). Thus, especially conscientiousness might moderate the relationship between HCC and hair collection method, that is, whether hair samples were collected self-administered or professionally. If one were

to obtain valid hair samples under self-administration conditions only from individuals with certain personality traits, one would have to assume that studies using self-collection of hair as collection method could lead to biased or non-representative results. It is therefore essential to investigate whether personality is a moderator of the relationship between collection method and HCC.

## 2. Method

### 2.1. Samples and procedure

This research was approved by the local ethics committee of the Technische Universität Dresden (dossier EK23012016, IRB00001473 and IORG0001076). Data from Sample 1 are from the Dresden longitudinal study of chronic stress and cognitive control (StressCog). A letter of invitation was sent to 8400 stratified randomly sampled citizens of the City of Dresden in Germany. Contact information was provided by the Residents' Registration Office of the City. An age range of 25–55 years was applied. Prerequisites for participation were a hair length of at least 3 cm at the occipital region of the scalp. In the present study the baseline data of the longitudinal study are used, which in total comprised HCC samples of a population-wide sample of  $N = 509$  participants. For hair sample collection, a between-subjects design was used. Participants were given the choice to either collect their hair samples at home with the help of a second person (home group) or to visit the lab at university and receive a professional hair collection by our trained staff (lab group).

For 23 of the 509 individuals (4.5 %) cortisol concentration was below quantification levels due to insufficient hair sample quality (e.g. insufficient amount of hair or unclear beginning of the hair strain) and/or values below the limit of detection ( $< 0.09$  pg/mg; [Gao et al., 2013](#)). Four individuals had a cortisol concentration of  $> 90$  pg/mg, which were excluded from analyses in line with other studies (see e.g., [Braig et al., 2015](#); [Gao et al., 2013](#)). The first applied to 21 (5.3 %) and the latter to three (0.8 %) individuals from the home group ( $n = 398$ ) while two (1.8 %) and one (0.9 %) participants were excluded for these reasons in the lab group ( $n = 111$ ). Thus, the final sample considered for statistical analysis consisted of 482 participants (66 % females) with an age range of 25–55 years ( $M = 38.55$ ;  $SD = 8.87$ ). Of these individuals, a total of 108 participants decided to come into the lab (51 % female; age  $M \pm SD = 38.91 \pm 8.39$ , range between 26 and 54 years), while 374 individuals collected their hair sample at home (70 % female; age  $M \pm SD = 38.45 \pm 9.02$ , range between 25 and 55 years). In case of a self-administrated hair sample collection, the participants received all materials and information needed for hair collection via letter. The letter included an aluminum envelope, three small loops, a questionnaire for sociodemographic, hair, and lifestyle characteristics, and a pre-franked return envelope. Additionally, a brief instruction was enclosed including a web link to an instructional video on self-collecting hair. Access to the personality questionnaire and the questionnaires measuring sociodemographic and lifestyle-related information was provided via online link. For compensation participants received 10€ as well as an individual feedback of their questionnaire data and hair cortisol levels.

A second sample (Sample 2) could be used to further explore the role of personality as moderator of the relationship between collection method (self- vs. professional) and HCC. An advantage of this sample was that the study design allowed to investigate not only the moderating role of the personality of the hair sample donor (as in Sample 1) but also that of the hair sample collector. Participants came pairwise in the lab (the partner choice was self-administered) and hair samples were collected under two successive test conditions. In the first condition (professional), hair samples of each pair of participants were taken professionally by the trained experimenter. In the other condition (self), participants were asked to take a hair sample from each other with the help of their partner. In order to avoid sequence effects, the pairwise

assignment to the sequence of the two conditions was randomized. For the collection of hair samples from their partners, the participants received a detailed written instruction on how to collect a hair strand from the scalp as well as a web-link with an instructional video (about 3:30 min). They were given a scissor, a comb, an aluminum envelope (for hair sample storage), small loops and a hair clip. The examiner left the room when the participants collected their hair samples. Prior to hair sample collection, participants were asked to fill out the NEO-FFI to measure FFM personality traits as well as a questionnaire on lifestyle factors and hair characteristics, as outlined below. Because the NEO-FFI was included in the study somewhat after the start of the study and since some self-administered partners refrained from reporting their personality ( $n = 4$ ), data of the hair sample donor and the hair sample collector, respectively, were at hand for  $n = 40$  individuals (92.5 % female; age  $M \pm SD = 25.15 \pm 8.65$ , range between 19 and 58 years) and for  $n = 36$  individuals (88.9 % female; age  $M \pm SD = 25.39 \pm 8.89$ , range between 19 and 56 years) while for a total of  $N = 50$  individuals HCC was available (88.0 % female; age  $M \pm SD = 25.0 \pm 9.09$ , range between 19 and 58 years). The sample was primarily used to further investigate the role of personality (particularly of hair collectors), but we will also report the main effect of the collection method for the 50 individuals in the result section.

As in Sample 1, a prerequisite for participation of this healthy student sample was a hair length of at least 3 cm at the occipital region of the scalp. The participants received course credit for their participation.

The use of (corticosteroid) medication was assessed via self-report. In Sample 1, one individual used a topical glucocorticoid ointment for acute dental treatment, two further individuals used topical synthetic glucocorticoids (budesonide and beclometasone), which were applied via an asthma inhaler. However, there were no conspicuous cortisol data for these individuals nor did the results change substantially when excluding these individuals from analyses.

## 2.2. Material

### 2.2.1. Collection of hair samples

The hair samples (consisting of three hair strands with a diameter of about 3 mm each) were taken from the occipital region of the scalp. Prior to the collection of the hair sample, a straight line was combed in the participant's hair. The strand of hair that overlapped the combed line was then fixated with a hair clip. Next, a loop was used to isolate a strand of hair with a thickness of about a pencil-mine. The strand of hair was cut with a pair of scissors as closely to the scalp as possible. The hair sample was then stored in an aluminum envelope (Pragst and Balikova, 2006) to protect it from UV-light and possible contaminating influences.

### 2.2.2. Cortisol extraction of hair samples

For Sample 1, the first scalp-near 3 cm segments of hair were processed. Samples of whole, non-pulverized hair were weighed to 7.5 mg and then washed twice with 3 mL of isopropanol (Gao et al., 2013). Steroid extraction was carried out with 1.8 mL of methanol. Subsequently, cortisol concentrations were determined by liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS) according to Gao et al. (2013) and Gao, Kirschbaum, Grass, and Stalder (2016), respectively. Intra- and interassay coefficients of variation for this LC-MS/MS hair cortisol analysis have been observed to range between 3.7 and 8.8 % in our lab (Abell et al., 2016; Gao et al., 2013). For further validation parameters of this method, see also Russel et al. (2015) and Gao et al. (2016, 2013).

The procedure of Sample 2 was conducted in accordance with a previously published protocol (Kirschbaum et al., 2009). Prior to the cortisol extraction, the first scalp-near 3 cm hair strands were processed as outlined above and washed twice with 3 mL of isopropanol. The actual extraction process was conducted with 1.8 mL of methanol. Finally, cortisol determination was done using immunoassay with luminescence detection (IBL international, Hamburg, Germany). Inter-

and intraassay coefficients of variation of the used assay are below 8 % (see e.g., Kirschbaum et al., 2009). Further evaluation of this immunoassay including data demonstrating strong intercorrelations between this and other immunoassays as well as between immunoassays and LC-MS/MS for HCC determination are given in Russell et al. (2015).

### 2.2.3. (Personality) questionnaires

In Sample 1, the 21-item BFI-K (Rammstedt and John, 2005) and in Sample 2, the 60-item NEO-FFI questionnaire (Costa and McCrae, 1992; German version: Borkenau and Ostendorf, 2008) was used to measure the FFM personality trait dimensions: neuroticism (N), extraversion (E), openness to experience (O), agreeableness (A) and conscientiousness (C). In Sample 1 ( $N = 482$ ), Cronbach's Alpha were  $\alpha = .80$  for N,  $\alpha = .86$  for E,  $\alpha = .71$  for O,  $\alpha = .65$  for A, and  $\alpha = .72$  for C, being in agreement with the validation study of the short FFM inventory by Rammstedt and John (2005). In Sample 2 ( $N = 40$ ), similar internal consistencies were observed:  $\alpha = .80$  for N,  $\alpha = .65$  for E,  $\alpha = .69$  for O,  $\alpha = .64$  for A, and  $\alpha = .72$  for C.

In Sample 1, beside personality, a variety of hair characteristics, sociodemographic and lifestyle variables that have been previously suggested to potentially influence HCC were assessed as possible confounders. In particular, sex, the amount of hair washes, household size, and BMI (Braig et al., 2015; Ouellet-Morin et al., 2016; Stalder et al., 2012a) as well as head sweating, ultraviolet (UV) ray exposure, alcohol consumption, hair thickness/loss, and physical activity (Grass et al., 2016; Russell et al., 2014; Stalder et al., 2012b; Wosu et al., 2013) were recorded by questionnaire. Specifically, alcohol was measured ordinally with seven response categories to the question "In the last three months, how often did you drink alcohol?" ranging from "never" to "two times or more a day". Hair thickness was measured with the response categories "thin", "normal", or "thick". Hair loss was answered with a dichotomous "yes" or "no" answer to the question: "Do you have hair loss?". Hair washes were measured by hair washes per week. Head sweat had three response categories to the question "Are you aware of sweating heavily on the head?" with responses being: "no", "maybe" and "yes". Ultraviolet rays (UV) exposure was measured with the average minutes spent outside per day during the last three month. Physical activity was measured with the amount of time (in hours) of physical activity per week. Moreover, BMI (in kg/m<sup>2</sup>) and the number of individuals in the household were assessed.

### 2.3. Statistical analyses

Statistical analyses were conducted with SPSS 25 (SPSS Inc., Chicago, IL, USA). In Sample 1, we examined whether there were differences in HCC between participants who collected their hair at home and those who let it be professionally collected in the lab. To test this main question of our study, an analysis of covariance was utilized with logarithmized HCC values as dependent variable and collection method as factor. Moreover, as outlined above, potentially confounding variables were included as covariates because they may obscure the outcomes and conclusions of the study. Accordingly, prior to this main analysis, it was examined whether the compared collection method groups (lab vs. home) differ with respect to sociodemographic, lifestyle, or personality variables using t-tests for all continuous variables, the non-parametric Mann-Whitney  $U$  test for ordinal scaled variables, and  $\chi^2$  tests for all categorical variables. Levene tests for homogeneity were run and consequently, unequal variances for t-tests were utilized when appropriate. Further, correlations between HCC and the potential confounding variables were estimated. Note that we conservatively included all variables as covariates in our main analysis for which lab/home group differences or associations with HCC at a significance level of  $p < .10$  occurred. For all analyses, the respective  $N$  will be reported in the results section due to missing cases in some questionnaire-based variables. Note, however, that the number of cases was never below  $N = 428$ .

Beside our main analysis, we further examined the potential

**Table 1**

Differences between hair sample collection groups (lab vs. home) in socio-demographic, hair, lifestyle and FFM personality variables (Sample 1).

Independent variable: Collection Method (lab/home)	T/chi <sup>2</sup> value	df	p	N
Age <sup>1</sup>	0.47	480	.636	482
Sex <sup>3</sup>	14.04	1	<.001	482
Persons in household <sup>1</sup>	-0.35	468	.725	470
BMI <sup>1</sup>	-0.26	468	.795	470
Alcohol <sup>2</sup>			.791	470
Hair thickness <sup>2</sup>			.239	476
Hair Loss <sup>3</sup>	0.12	1	.729	474
Hair washes <sup>1</sup>	2.22	472	.027	474
Head sweat <sup>3</sup>	2.72	2	.257	476
UV exposure <sup>1</sup>	1.32	118.95	.189	474
Physical activity <sup>1</sup>	0.27	426	.785	428
Neuroticism <sup>1</sup>	-0.12	477	.990	479
Extraversion <sup>1</sup>	-0.05	156.94	.959	479
Openness <sup>1</sup>	-1.79	477	.073	479
Agreeableness <sup>1</sup>	-1.06	477	.291	479
Conscientiousness <sup>1</sup>	-1.83	477	.068	479

Annotations: BMI = Body Mass Index; Test statistics for <sup>1</sup> t-test, <sup>2</sup> Mann-Whitney-U test, and <sup>3</sup> chi<sup>2</sup> test is given.

moderating influence of personality factors. First, a moderated regression analysis was conducted using Sample 1. Cortisol data were regressed on the collection method factor (lab vs. home), the five (beforehand centered) personality variables, and the interaction terms of collection method and each personality factor. Moreover, as in our main analysis, relevant covariates were considered (see above). One caveat of Sample 1 data is that we could only measure the traits of individuals who got their hair collected and not of the collectors themselves. It can be assumed, however, that in such close dyadic interactions the personality traits of the hair donor may to a certain extent influence the collector during hair collection. For instance, a very diligent donor could influence the collector such as by inquiry or by insisting to follow the collection instructions precisely (Chiaburu et al., 2011; Emilsson et al., 2011). It could be additionally interesting, however, to measure the traits of the collectors. This was the objective of the (experimental) within-subjects design of Sample 2, in which we also assessed the personality traits of the hair collectors. Using two mixed models, we thus, investigated whether there are differences in HCC between the two experimental conditions (professionally vs. self) and whether the personality of the hair donor (model 1,  $N = 40$ ) and additionally of the hair collector (model 2,  $N = 36$ ) may moderate this relationship which would be indicated by significant interaction effects of the personality factors (included as covariates in the model) with the repeated measures factor.

### 3. Results

#### 3.1. Descriptives of HCC

The cortisol concentrations of Sample 1 ( $N = 482$ ) were between 0.57 and 75.87 pg/mg ( $M = 6.07$ ,  $SD = 7.39$ ), in which the professionally collected hair samples ( $n = 108$ ) ranged between 0.57 and 74.25 pg/mg ( $M = 6.65$ ,  $SD = 8.94$ ), whereas the self-collected hair samples ( $n = 374$ ) ranged between 0.57 and 75.87 pg/mg ( $M = 5.91$ ,  $SD = 6.88$ ).

The concentration of cortisol in the hair samples of Sample 2 ( $N = 50$ ) ranged between 0.33 and 32.23 pg/mg ( $M = 7.67$ ,  $SD = 8.02$ ) for the professionally collected hair segments. For self-collected hair samples, the segments' cortisol concentrations were between 0.26 and 39.83 pg/mg ( $M = 7.87$ ,  $SD = 8.42$ ).

#### 3.2. Differences in HCC dependent of hair sample collection method

Next, we investigated whether there are differences in HCC dependent on hair sample collection method in Sample 1. Beforehand factors

**Table 2**

Results of the ANCOVA on HCC differences depending on collection method (lab vs. home), controlled for the effects of potential confounders (Sample 1).

Source	df	F	p	$\eta_p^2$
adjusted model	9	3.79	<.001	.071
Constant Term	1	12.31	<.001	.027
Lab_Home	1	1.05	.307	.002
Sex	1	1.18	.277	.003
BMI	1	10.56	.001	.023
Alcohol	1	1.60	.207	.004
Persons household	1	3.32	.069	.069
Hair washes	1	0.56	.456	.001
Head sweat	1	7.16	.008	.016
Openness	1	0.38	.538	.001
Conscientiousness	1	0.04	.836	<.001
Error	449			
Total	459			
adjusted total variation	458			

Annotations:  $R^2 = .071$ , adjusted  $R^2 = .052$ .

that potentially influence HCC or/and for which differences in the two compared groups (lab vs. home) occurred were analyzed, as outlined above.

As shown by Table 1, the two hair sample collection methods (lab vs. home) significantly differed with respect to gender distribution ( $\chi^2 = 14.04$ ,  $p < .001$ ) whereby female participants were more frequently represented in the home group, while in the lab group both genders were equally represented (females in lab: 51 % vs. home: 70 %). Group differences further occurred regarding the variable hair washes ( $T = 2.22$ ,  $p = .027$ ), with a higher number of hair washes per week in the lab than in the home group ( $M \pm SD$  home =  $3.50 \pm 1.78$  vs. lab =  $4.08 \pm 3.83$ ). Moreover, there was a trend to significance regarding the personality factors openness ( $T = -1.79$ ,  $p = .073$ ) and conscientiousness ( $T = -1.83$ ,  $p = .068$ ) whereby individuals who choose to collect their hair samples at home reported slightly higher O-values ( $M \pm SD$  home =  $3.86 \pm 0.68$  vs. lab =  $3.72 \pm 0.67$ ) and higher C-values ( $M \pm SD$  home =  $3.86 \pm 0.66$  vs. lab =  $3.73 \pm 0.71$ ).

With respect to associations of HCC with sociodemographic, personality, hair and life style-related variables, the following correlations (spearman's rho) occurred. HCC was significantly positively associated with BMI ( $r = .21$ ,  $p < .001$ ;  $N = 470$ ), head sweating ( $r = .18$ ,  $p < .001$ ,  $N = 476$ ), alcohol ( $r = .11$ ,  $p = .017$ ,  $N = 470$ ), and the number of persons in the household ( $r = .10$ ,  $p = .033$ ,  $N = 470$ ). Regarding gender slightly higher HCCs were observed for men ( $r = -.11$ ,  $p = .016$ ,  $N = 482$ ). For all other variables  $p$  was  $> .10$ .

That is, the ANCOVA conducted ( $N = 459$ ) included the hair sample collection method (lab vs. home) as independent factor variable, HCC as dependent variable and eight covariates (see Table 2). As indicated by the test statistics, HCC was likely independent of collection method ( $F = 1.05$ ,  $p = .307$ ). Only BMI ( $F = 10.56$ ,  $p = .001$ ) and head sweating ( $F = 7.16$ ,  $p = .008$ ) significantly explained variance in HCC.

We further examined whether the result of no difference between the collection methods could be replicated in the within-subjects design for the  $N = 50$  individuals for whom cortisol was available. Logarithmized HCC values of self- and professionally collected hair samples were highly correlated ( $r = .84$ ,  $p < .001$ ) and by means of an repeated measures model, no significant difference between the collection methods in HCC was observed ( $F_{1,49} = 1.64$ ,  $p = .206$ ,  $\eta_p^2 = .03$ ). Note that socio-demographic, hair and lifestyle variables were considered as potential confounders, as outlined above. However, since none of the variables in Sample 2 were significantly related to the HCC criterion (all  $p > .10$ ), we have not considered covariates in the analysis.

#### 3.3. The influence of personality traits as moderators

Additionally, in Sample 1, moderated regression analyses were run to test whether FFM personality traits moderate the influence of the two

collection methods (lab vs. home) on HCC ( $N = 459$ ). There was no evidence for a significant effect of hair collection method ( $b = -0.11$ ;  $p = .328$ ). Of the covariates considered (see above), only head sweat ( $b = 0.11$ ;  $p = .007$ ) and BMI ( $b = 0.02$ ;  $p = .002$ ) showed significant main effects. There were no further significant main effects (all  $p > .05$ , see also Table A1 in the Appendix). None of the FFM dimensions, namely neuroticism ( $b = -0.03$ ;  $p = .734$ ), extraversion ( $b = 0.03$ ;  $p = .708$ ), openness ( $b = -0.07$ ;  $p = .491$ ), agreeableness ( $b = -0.09$ ;  $p = .340$ ), and conscientiousness ( $b = 0.01$ ;  $p = .904$ ) significantly moderated the relationship between collection method and HCC. However, as outlined above, in Sample 1, personality data are related to the hair donor and not to the hair sample collector.

Therefore, we conducted additional analyses on personality-based moderating effects using Sample 2, where data on the personality of the hair sample donor as well as of the hair sample collector were available. In a first mixed model with professionally vs. self-collected HCC and the FFM scores of the hair sample donor ( $n = 40$ ), the result of Sample 1 were replicated. No significant difference between the collection methods was observed ( $F_{1,34} = 0.04$ ,  $p = .837$ ,  $\eta_p^2 < .01$ ). Further, none of the donor's personality traits moderated the relationship between collection method and HCC to a significant extent (all  $p > .227$ ). The same was true in the model that considered the FFM traits of the hair sample collectors as moderators ( $n = 36$ ). For none of the personality factors a significant interaction with collection method was observed (all  $p > .317$ ).

#### 4. Discussion

Hair cortisol measurement is a comparatively novel method. This makes the validation of typical sample collection methods of hair crucial. Accordingly, the main aim of this study was to examine whether participants differ regarding HCC when hair samples are collected by themselves (e.g. in domestic settings), as compared to a professionally collected in the lab. In addition, it was investigated whether there is a moderating influence of central personality traits of the FFM on the relationship between hair sample collection method and HCC.

First, the two compared sample collection methods did not significantly differ from each other in terms of HCC. We observed no significant difference in HCC between professionally collected samples and samples collected by the participants themselves with the help of a partner. This was suggested by the results of a large population-wide sample of  $N = 482$  participants using a between-subjects design (Sample 1) which compares self-collected hair samples at home with professionally collected hair samples in the lab. Similarly, in a student sample of  $N = 50$  using a within-subjects design (Sample 2) there were also no significant differences between collection methods in HCC. In Sample 1, we also considered potential confounding factors that might affect HCC. Of these variables, head sweating, BMI, alcohol and household size showed small positive associations with HCC. Moreover, men exhibited somewhat higher HCC values than woman. In general, these findings support previous associations of these factors with HCC (Braig et al., 2015; Ouellet-Morin et al., 2016; Stalder and Kirschbaum, 2012; Wosu et al., 2013). However, when these variables were considered together in a regression model, only head sweating and BMI showed a significant incremental association with HCC over and above the respective other predictors. The relationship of BMI with HCC is supported by several studies (Abell et al., 2016; Stalder et al., 2012a). There is also support for the role of head sweating to potentially influence HCC (e.g., Russell et al., 2014), while other studies found no significant effect of (induced) sweating on HCC (e.g., Grass et al., 2015). However, given the assumed pathways of cortisol incorporation into hair, sweat and/or sebum is considered an additional source of incorporation and may therefore be a potential explanation for the positive association between head sweat and HCC in our study (Russell et al., 2014; Stalder and Kirschbaum, 2012).

In sum, the results of the present study suggest that self-

administered hair sample collection such as by the help of a partner in domestic settings is possible without a substantial difference in HCC relative to a professional hair sample collection. However, we observed that the number of hair strands below quantifiable HCC due to insufficient hair sample quality and/or values below the detection limit ( $< 0.09$  pg/mg; see e.g., Gao et al., 2013) was larger in participants who chose to self-collect their hair (5.3 %) than in participants who came in the lab for hair collection (1.8 %). So, with respect to hair collection in domestic settings a somewhat larger sample loss may possibly be expected in future studies. Nevertheless, our data also suggest that there is a great interest among the participants to collect hair in their familiar environment. In Sample 1, where the participants had the choice between hair collection at home or in the laboratory, about 78 % opted for self-collection of hair in the domestic setting. Thus, it is expected that offering this option will increase the willingness of individuals to participate in studies with HCC measurement. In order to limit the number of hair samples for which adequate HCC determination is not possible, such as because an insufficient amount of hair has been returned to the lab, we recommend providing comprehensive study information how to collect the hair sample also including an easy-to-follow instructional video format. We have the clear impression that video-based instructions offer a comparatively simple and standardized approach to potentially increase the accuracy of self-collection of hair.

Although no substantial differences in HCCs were observed between hair collection methods in general, a further question of this study was whether central personality traits could drive differences in HCCs depending on hair collection method. However, no significant interaction effects between the Big Five personality traits with hair collection method were found, neither in Sample 1 for the hair donor, nor in Sample 2 considering the personality of both the hair donor and the hair collector. Based on previous research, it was assumed that especially conscientiousness could be a moderator of the relationship between hair collection methods and HCC. It has been shown that conscientiousness plays a role in job-related task adherence (Bakker et al., 2012; Debusscher et al., 2017; Hui-Hua and Schutte, 2015), commitment behavior (Chiaburu et al., 2011) and in treatment adherence of patients (O'Cleirigh et al., 2007; Stilley et al., 2004). In addition to the general behavioral tendencies associated with conscientiousness such as being reliable, disciplined, and systematic, such studies may suggest that conscientious individuals would show a stronger commitment to a task at hand. That is, differences in conscientiousness might have been especially relevant in the domestic setting where hair samples were self-collected and possibly less so in the lab, where hair was professionally collected. However, the present results indicate that there is no considerable influence of conscientiousness on HCC depending on sample collection method, neither in terms of the personality of the hair donor (Sample 1 and Sample 2), nor that of the hair collector (Sample 2).

Because previous findings also suggest a role of the other FFM dimensions on task/job performance and commitment or adherence behavior such as to follow medical instructions (Chiaburu et al., 2011; Emilsson et al., 2011; Griffin and Hesketh, 2004), an influence of these traits have been potentially possible. However, there was also no moderating influence of the other FFM traits on HCC depending on hair collection method in both samples. Thus it may be argued, that FFM personality factors may not play a substantial role in hair sample collection methods and associated cortisol concentrations in hair, respectively.

##### 4.1. Strengths and limitations

In both samples, using a between-subjects design (Sample 1) as well as a within-subjects design (Sample 2), we found no significant differences in HCC between professional and self-collected hair samples. Sample 1 provided a relatively large population-wide sample with a broad age range which is a clear strength, making our data more

**Table A1**

Interaction effects between FFM personality traits as well as sociodemographic, hair and lifestyle factors with hair sample collection (lab vs. home) using moderated regression analysis.

Model	<i>b</i>	<i>SE</i>	<i>p</i>	CI (lower limit)	CI (upper limit)
Intercept	1.24	0.27	<.001	0.71	1.76
Lab_Home	−0.12	−0.08	.328	−0.33	0.11
sex	−0.04	0.07	.577	−0.18	0.10
wash	0.01	0.01	.461	−0.02	0.03
sweat	0.11	0.04	.007	0.03	0.19
alcohol	0.03	0.03	.205	−0.02	0.08
BMI	0.02	0.01	.002	−0.01	0.03
persons in household	0.04	0.02	.086	−0.01	0.09
Neuroticism	0.02	0.16	.923	−0.29	0.32
Extraversion	−0.07	0.14	.633	−0.35	0.21
Openness to experience	0.16	0.19	.400	−0.21	0.52
Agreeableness	0.15	0.18	.386	−0.19	0.50
Conscientiousness	−0.02	0.20	.918	−0.41	0.37
Neuroticism * Lab_Home	−0.03	0.09	.734	−0.20	0.14
Extraversion * Lab_Home	0.03	0.08	.708	−0.12	0.18
Openness to experience * Lab_Home	−0.07	0.10	.491	−0.27	0.13
Agreeableness * Lab_Home	−0.09	0.10	.340	−0.28	0.10
Conscientiousness * Lab_Home	0.01	0.11	.904	−0.20	0.22
Adjusted R <sup>2</sup>	0.04 ( <i>p</i> = .005)				

Annotations. *N* = 459.

representative to the general population. In this sample given our ANCOVA analysis with *N* = 459 and an alpha of .05 we were able to detect small effects of *f* = .15 with a power of .89. Although Sample 2 consisted of a relatively small sample of *N* = 50, given the high correlation between the repeated measures of *r* = .84, effects of *f* = .15 could be detected with a power of .95 (G\*Power 3.1.9.2; Faul et al., 2014).

Beside the main research question whether there are differences in HCC depending on hair collection method an additional question was on the moderating influence of personality traits on this relationship. Although personality data were available for hair donors in Sample 1 an overall picture of the influence of personality could be weakened by the lack of data on personality traits of hair collectors. This, however, was addressed by Sample 2, which was partly limited by the relatively small sample size and the fact that the participants were students. Nevertheless, to further strengthen the validity of our results future research should replicate the findings using large population-wide samples.

Note that LC-MS/MS vs. immunoassays are known to generate different cortisol concentration ranges, which, however, does not limit the results as both samples are not directly compared (see Russell et al., 2015, also for intercorrelations between the analytical methods). Further, beside self-report data on alcohol consumption, future studies should also measure alcohol markers in hair such as ethyl glucuronide (EtG) to better estimate participants' history of drinking behavior (Oppolzer et al., 2019).

## 5. Conclusions

The results of the present study using two independent samples revealed no significant differences between self- and professionally collected hair samples regarding HCC with the exception of a slightly larger sample loss in domestic settings due to hair samples with insufficient quality and/or values below the limit of detection. Furthermore, no meaningful influence of the examined moderators, that is the FFM personality traits could be observed. Additionally, in line with previous results some sociodemographic variables, lifestyle and hair characteristic factors influenced HCC values. However, only BMI and head sweating showed incremental validity in explaining variance in HCC. In sum, the findings of our study could be important because self-collected hair samples offer logistical and monetary advantages and may be an

efficient method to gain larger sample sizes. To invite participants into the lab and to provide lab personnel to professionally collect hair samples is not only a logistical effort and time consuming, but also expensive. Moreover, individuals might be more willing to take part in a study, if they do not have to leave their home in order to participate or when they live far from the lab. This would also be true for those who are not able to leave their home such as ill, disabled, or very old individuals. All in all, the results of this study suggest that self-collection of hair is a viable and economical method for measuring long-term cortisol concentrations in hair.

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### Open data

Research data are available under <https://osf.io/XXXX/https://osf.io/XXXX/>

## Appendix A

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