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ORIGINAL ARTICLE

Chronic stress indicated by hair cortisol concentration in anaesthesiologists and its relationship to work experience and emotional intelligence

A cross-sectional biomarker and survey study

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BACKGROUND Anaesthesia is a stressful medical specialty. The reaction to stress is constituted by behavioural, psychological and physiological components. Chronic physiological stress can have negative consequences for health.

OBJECTIVES First, we hypothesised that chronic physiological stress is higher for both beginning and late-career consultant anaesthesiologists. Second, we hypothesised that individuals high in emotional intelligence endure lower physiological stress.

DESIGN Cross-sectional biomarker and survey study.

SETTING Participants were recruited during the May 2019 annual meeting of the Dutch Anaesthesia Society.

PARTICIPANTS Of the 1348 colleagues who attended the meeting, 184 (70 male/114 female) participated in the study. Of the study participants, 123 (67%) were consultant anaesthesiologists (52 male/71 female) and 61 (33%) were resident anaesthesiologists (18 male/43 female). Exclusion criteria were endocrine disorders and not having enough hair. Also, experience of a recent major life event led to exclusion from analysis of our hypotheses.

MAIN OUTCOME MEASURES Chronic physiological stress was measured by hair cortisol concentration. Emotional intelligence was assessed using a validated Dutch version of the Trait Emotional Intelligence Questionnaire. As secondary measures, psychological sources of stress were assessed using validated Dutch versions of the home-work interference (SWING) and the effort-reward imbalance questionnaires.

RESULTS In support of Hypothesis 1, hair cortisol concentration was highest among early and late-career consultant anaesthesiologists (quadratic effect: $b = 45.5$, SE = 16.1, $t = 2.8$, $P = 0.006$, $R^2 = 0.14$). This nonlinear pattern was not mirrored by self-reported sources of psychological stress. Our results did not support Hypothesis 2; we found no evidence for a relationship between emotional intelligence and physiological stress.

CONCLUSION In the early and later phases of an anaesthesiologist's career, physiological chronic stress is higher than in the middle of the career. However, this physiological response could not be explained from known sources of psychological stress. We discuss these findings against the background of key differences between physiological and psychological stress.

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Introduction

Anaesthesiology is considered a stressful medical specialty. Anaesthesiologists work long and unpredictable hours and often have to perform under time pressure in situations that are potentially life-threatening for the patient.[1,2] When an individual is repeatedly or continuously exposed to stress, that individual is assumed to be

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exposed to chronic stress. In stress theories, the reaction to stress is assumed to be composed of behavioural, psychological and physiological components. Initially, these reactions are adaptive in that they help the individual to cope with the stress. However, when these reactions are sustained, as happens in chronic stress, they affect mental and physical health negatively.[3]

Behavioural consequences of chronic stress in anaesthesiologists are, for example, poor performance at work and a higher risk of addiction to smoking, alcohol or drugs. Psychological consequences include job dissatisfaction and symptoms of burnout and depression.[4,5] Physiological consequences include increased concentrations of catecholamines and glucocorticosteroids such as cortisol in blood and tissues. These can cause various negative outcomes, such as higher risks of hypertension, coronary artery disease, peptic ulceration, atherosclerosis and obesity.[3] In addition, chronic stress increases susceptibility to infections.[6] This 'wear and tear' that the body experiences because of repeated physiological responses to psychosocial stress is known as allostatic load.[3]

Work-related stress in anaesthesiologists has also been shown to be associated with elevated levels of cortisol.[7–10] Recent methodological developments allow researchers to measure cortisol in hair, as well as in plasma, urine and saliva.[11] At any given time, deposits of cortisol in hair are proportional to circulating cortisol concentrations, and therefore hair cortisol concentration (HCC) can be used retrospectively as a biological measure of chronic stress and allostatic load.[12]

Previous research has suggested that stress is high in new consultants in anaesthesia, mostly because they need to work unsupervised or work with too little professional support. A feeling of needing to prove oneself may add to this stress.[13,14] However, it has been suggested that the profession is also relatively stressful at the end of the career, as older anaesthesiologists have more difficulty dealing with long and irregular working hours and keeping up with an ever advancing work environment.[15,16]

Not all individuals are equally likely to suffer from stress.[17] The negative emotions that are released by stress can affect the ability to cope with the demands of the situation. Previous research suggests that emotional intelligence (EI), a personality trait, affects the way people control and manage these emotions. Thus, EI moderates the appraisal and experience of stress. Indeed, several studies have found that stress responses were attenuated in individuals high in EI.[18,19]

We hypothesised first that anaesthesiologists at the beginning or end of their consulting careers will experience higher levels of chronic stress, as indicated by hair cortisol concentration, than an individual in the middle of their career. The relationship between HCC and experience will therefore have a U-shape. Second, we believed that a high level of emotional intelligence would be negatively related to chronic stress as indicated by HCC. In addition to testing these hypotheses, we also explored how different sources of stress vary over the career span, potentially explaining variation in HCC. Specifically, we examined the imbalance between work-related effort and work-related reward. We also examined the possible interference of the home situation on the stress at work.

Methods

Ethical approval for this study (Ethical Committee N° 2019-5259) was provided by the local ethics committee (Commissie Mensgebonden Onderzoek regio Arnhem-Nijmegen) on 8 April 2019. Written informed consent of the participants was obtained before inclusion.

The study had a cross-sectional design. The main predictor variables were work experience (in years) and trait emotional intelligence. The main outcome variable was the concentration of cortisol in hair, a physiological measure of chronic stress. The secondary outcome variables were effort–reward imbalance and home–work interference, which are potential sources of psychological stress. All main predictors and outcomes were treated as continuous variables.

We obtained a sample of anaesthesiologists from attendees at the May 2019 annual meeting of the Dutch Anaesthesia Society. They were either asked to participate in the study, or volunteered spontaneously. Attendees were informed of the study by the Society's chair at the plenary session that opened the meeting.

Exclusion criteria for the study were insufficient hair on the back of the scalp, a history of Cushing syndrome, Addison's disease or diabetes mellitus, or experience of a major life event (MLE) in the past 3 months because the consequent increase in HCC is not distinguishable from an increase caused by chronic stress.[12] MLEs are, for example, loss of a loved one, loss of job, a serious illness or injury, marriage, divorce or becoming a parent.

Demographic information such as age, sex, position and type of hospital was gathered via a questionnaire. Work experience was measured (in years), either as a resident or as a consultant. The questionnaire included a brief explanation of MLEs, and included an open-ended question that asked about any MLEs in the past three months. Participants' responses were later coded according to predefined criteria.

Cortisol concentration was measured from the proximal 3 cm of a sample of hair. The samples contained 200 to 300 hairs and were cut from the vertex of the scalp by a professional hair artist. As hair grows approximately 1 cm per month, the proximal 3 cm of hair correspond with growth in about the past 3 months. In a laboratory, the hair was minced, cortisol was extracted and cortisol

concentrations were determined by liquid chromatography-mass spectroscopy (LC-MS/MS):[20] for the exact procedure, see Appendix 1, http://links.lww.com/EJA/A435.

To measure emotional intelligence, we used a validated Dutch version of the Trait Emotional Intelligence-Questionnaire, short form (TEI-Que SF). Trait Emotional Intelligence (TEI) captures a set of affect-related traits, which are scattered throughout the five dimensions of the Big Five model of personality.[21] The TEI-Que SF measures TEI in four dimensions on a 1 to 7 Likert-scale: Well-being (six items), Self-control (six items), Emotionality (eight items) and Sociability (six items), and also provides a total score.[21,22] The values of Cronbach α in our sample were 0.71, 0.68, 0.66, 0.65 and 0.87, respectively, and therefore acceptable.

To explore known sources of work-related stress, we used the short form of the Effort–Reward Imbalance (ERI) questionnaire. To assess the imbalance between effort and reward, it is commonly advised to calculate their ratio. A number close to zero indicates a favourable condition (low Effort/high Reward) and a number above one signifies an unfavourable condition (high Effort/low Reward).[23,24] The Effort and Reward-scales (10 items, 1–4 Likert scale) of the ERI showed acceptable internal consistency with values of Cronbach α of 0.74 and 0.76, respectively. To explore possible influence stemming from the home situation on work stress, we assessed home–work interference using the SWING (Survey Work–Home Interaction NijmeGen)-questionnaire (nine items, 0–3 Likert-scale).[25] The scale for positive Home–Work interference (HWI) and the scale for negative HWI showed acceptable internal consistency with values of Cronbach α of 0.77 and 0.68, respectively.

Statistical analysis

To test Hypothesis 1, we carried out a quadratic regression analysis, which can be used to test hypotheses that involve a U-shaped relationship between two variables. Quadratic regression does not require to discretise years of experience, which would be associated with less statistical power and an increased chance of finding false positives.[26] Quadratic regression is different from linear regression, in that the regression equation includes not only a linear term (b_1*x) but also a quadratic term (b_2*x^2) for the predictor of interest. We included years of experience (linear) and years of experience (quadratic) as our predictors. HCC was the main outcome variable; we included sex (dummy coded) as a covariate.[27] As Hypothesis 1 applied to consultants, consultants and residents were analysed separately.

To test Hypothesis 2, we carried out linear regression analysis in the full sample, with TEI as the main predictor variable. Again, HCC was the main outcome variable; we corrected for sex.

Finally, in an exploratory fashion, we examined whether effort–reward imbalance and home–work interference behave in the same way as HCC. That is, we used years of experience to predict these two secondary outcome variables.

Participants who had missing data on HCC were excluded from analysis. The very few missing data points from the TEI, ERI and SWING questionnaires (e.g. because participants skipped an item) were dealt with as advised by the respective user manuals. There were no missing sociodemographic data.

Statistical analysis and data visualisation were performed using 'R' version 3.6.1 2019 (RStudio Inc, Vienna Austria).

For Hypothesis 1, based on 2000 simulations with the proposed statistical model (HCC = intercept + β1 * experience + β2 * experience^2), then for β2 = 0.30, 80% power is reached at a sample size of 120. For Hypothesis 2, based on 2000 simulations with the proposed statistical model (HCC = intercept + β1 * TEI), then for β1 = 0.30, 80% power is reached at $n = 90$.

We pre-registered our hypotheses and analyses plan at AsPredicted (registration ID = #23213, https://aspredicted.org/eg9xz.pdf) before we started data collection. All data (questionnaires and HCC values) were entered by research assistants in a certified electronic database (Castor EDC: www.castoredc.com). The database was locked after data entry and was checked by another research assistant. Participants either randomly participated or were randomly recruited by research assistants. The link to the permanent data storage is available from the corresponding author on reasonable request. All measures in this study are reported in this article.

Results

Table 1 shows the sociodemographic details of our sample. Of the 1348 resident and consultant anaesthesiologists who attended the 2019 meeting, a total of 184 colleagues (70 male/114 female) agreed and were eligible to participate in the study. About 25% of residents compared with 20% of the consultants reported an MLE in the past 3 months. These were excluded from the analyses reported below.

Table 2 shows the mean values for hair cortisol concentrations, the Trait Emotional Intelligence Questionnaire and the Home–Work Interference and Effort–Reward Imbalance questionnaires. In six consultants, the quality of the hair sample was insufficient to measure HCC.

Among very experienced consultants, we found a small cluster of samples with HCC above 90 pmol g^{-1}, bordering the upper limit for healthy individuals reported in the literature.[28] Although these samples could be considered outliers, we chose to include them in our analysis because, as one of those cases experienced an MLE,

Table 1 Sociodemographic variables of our sample of consultant and resident anaesthesiologists

	Total ($n = 184$)	Consultants ($n = 123$)	Residents ($n = 61$)
Sex			
Male	70 (38%)	52 (42.3%)	18 (29.5%)
Age	38.5 [26 to 68]	45 [31 to 68]	30 [26 to 42]
Relationship			
Single	14 (7.6%)	7 (5.7%)	7 (11.5%)
Married/In relationship	164 (89.1%)	110 (89.4%)	54 (88.5%)
Divorced[a]	6 (3.3%)	6 (4.9%)	
Children[b]			
Yes	95 (51.6%)	76 (61.8%)	18 (29.5%)
Major life event[c]			
Yes	39 (21.2%)	24 (19.5%)	15 (24.6%)
Hospital			
Academic centre	94 (51.1%)	45 (36.6%)	49 (80.3%)
General hospital	57 (31.0%)	47 (38.2%)	10 (16.4%)
Community hospital	31 (16.8%)	29 (23.6%)	2 (3.3%)
Specialty hospital	1 (0.5%)	1 (0.8%)	
Private clinic	1 (0.5%)	1 (0.8%)	
Full time percentage[c]	90 [0 to 100]	90 [0 to 100]	90 [80 to 100]
Night shifts			
Yes	140 [76.1%]	107 [87%]	33 [54.1%]

Data are median [range] or number (%). [a]Including widowed ($n = 1$). [b]Children beneath the age of 18 years. [c]In past 3 months.

Table 2 Hair cortisol concentration, trait emotional intelligence, home–work interference and effort–reward imbalance in our sample of consultant and resident anaesthesiologists

	Total ($n = 184$)	Consultants	Residents
HCC (pmol g^{-1})	$n = 176$[a]	$n = 116$	$n = 60$
Total group	16.3 ± 15.0	17.4 ± 17.4	14.1 ± 8.2
Major life event	19.0 ± 15.0	20.9 ± 18.6	16.0 ± 6.0
No major life event	15.6 ± 14.9	16.6 ± 17.1	13.5 ± 8.7
Questionnaires (scale)	n = 184[a]	n = 123	n = 61
Total TEI (1 to 7)	5.3 ± 0.58	5.3 ± 0.61	5.3 ± 0.53
Subdimensions of TEI			
Wellbeing (1 to 7)	5.8 ± 0.72	5.8 ± 0.75	5.8 ± 0.67
Self-control (1 to 7)	5.0 ± 0.89	5.1 ± 0.83	4.9 ± 0.86
Emotionality (1 to 7)	5.5 ± 0.67	5.5 ± 0.70	5.5 ± 0.62
Sociabilty (1 to 7)	4.7 ± 0.83	4.7 ± 0.89	4.8 ± 0.70
Home-work interference			
Positive (0 to 3)	1.4 ± 0.64	1.4 ± 0.67	1.4 ± 0.60
Negative (0 to 3)	0.56 ± 0.39	0.50 ± 0.36	0.67 ± 0.42
Effort-reward imbalance			
Reward (1 to 4)	3.0 ± 0.53	3.0 ± 0.61	3.1 ± 0.35
Effort (1 to 4)	3.0 ± 0.66	3.1 ± 0.66	2.8 ± 0.61
Effort/reward ratio	1.03 ± 0.37	1.1 ± 0.40	0.92 ± 0.24

Values are mean ± SD. HCC, hair cortisol concentration; TEI, trait emotional intelligence. [a]The discrepancy between the number of participants in HCC measurement and questionnaires is explained in the Results section.

the possibility that these high values of HCC in this category are indicative of experienced stress cannot be ruled out. The subject who reported an MLE was, of course, excluded from analysis of our main hypotheses. One case concerned a retired anaesthesiologist and was not included in further analysis. In the resident group, there was one outlier of 325 pmol g^{-1}. We suspect this may be a presentation of cortisol hypersynthesis.[28] This case was not included in further analysis.

Hypothesis 1: Years of experience and hair cortisol concentration

Among consultants, our analysis yielded a significant linear effect of years of experience ($b = 41.7$, SE = 16.9, $t = 2.5$, $P = 0.015$) and, as predicted, a significant quadratic effect ($b = 45.4$, SE = 16.1, $t = 2.8$, $P = 0.006$) (Fig. 1). The effect of sex was not significant ($b = -4.5$, SE = 3.5, $t = -1.3$, $P = 0.198$). Together, these predictors explained 14% of the total variance in HCC. In support of Hypothesis 1, HCC was higher both at the beginning and toward the end of a consultant anaesthesiologists' career. Specifically, according to our statistical model, HCC was lowest after about 11 years of work experience as a consultant. Next, we examined whether our main finding regarding Hypothesis 1 was sufficiently robust to including several control variables that may have plausibly affected HCC. For example, hair washing frequency did not have a significant influence (Table 3). This analysis suggests that the quadratic effect of years of experience, which we hypothesised and found, was not an artefact of any of these potential confounders. As mentioned above, several consultants had substantially higher HCC than others. Thus, to explore whether our main finding regarding Hypothesis 1 depended on these participants, we repeated our analysis after excluding

Fig. 1 Hair cortisol concentrations (HCC) of resident and consultant anaesthesiologists plotted against experience

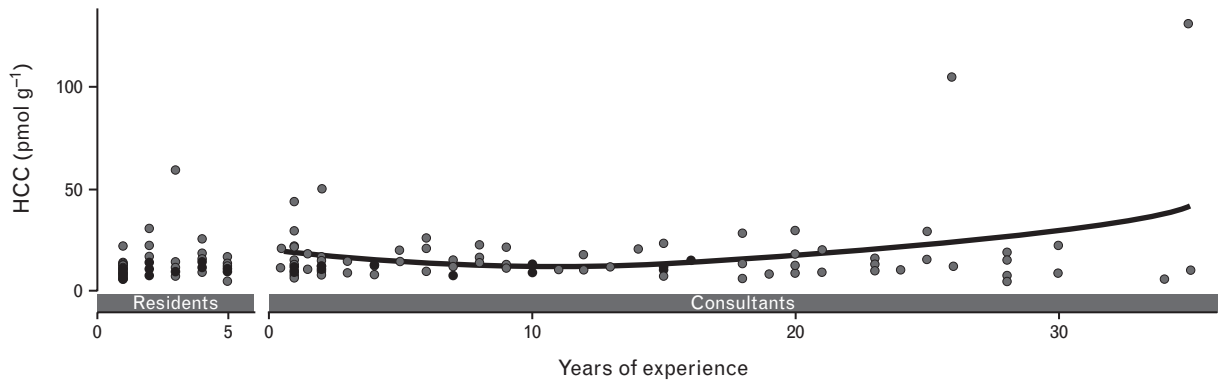


Table 3 Results from robustness analysis for Hypothesis 1

Term	*b*	SE	*t*	*P* value
Male sex	1.4	4.6	0.3	0.755
Dyed hair	10.1	4.7	2.2	0.034
Intense perspiration	7.5	3.9	1.9	0.060
Hair product use	1.5	3.5	0.4	0.669
Hair washing frequency				
less than once per week	Reference			
1 to 2 times per week	0.1	6.1	0.0	0.989
3 to 4 times per week	2.1	6.1	0.3	0.737
> 4 times per week	−6.0	6.2	−1.0	0.336
Corticosteroid use	−1.2	3.7	−0.3	0.748
Years of experience (linear)	40.3	18.0	2.2	0.028
Years of experience (quadratic)	56.3	16.1	3.5	0.001

See text for details.

those participants from our sample. In this analysis, there was no significant linear ($b = -5.6$, SE = 8.0, $t = -0.7$, $P = 0.486$), nor a significant quadratic effect ($b = 2.9$, SE = 7.6, $t = 0.4$, $P = 0.703$), of years of experience. We return to this finding in the Discussion.

Among residents, there was no relationship between years of experience and HCC, nor any influence of sex ($t < 3.4$, $P > .059$; Fig. 1).

Hypothesis 2: Trait emotional intelligence and hair cortisol

We found no support for our hypothesis, as trait emotional intelligence did not significantly predict hair cortisol concentration ($b = -0.6$, SE = 2.2, $t = 0.3$, $P = 0.786$). The effect of sex was again not significant either ($b = -1.5$, SE = 2.6, $t = -0.6$, $P = 0.571$).

Other analyses

To explore potential explanations for the pattern we found for consultants, we examined how sources of stress vary in relation to years of experience (Fig. 2). When using the effort–reward ratio as an outcome variable in consultants, we found there was no significant linear effect of years of experience ($b = 0.6$, SE = 0.4, $t = 1.4$, $P = 0.161$). However, as shown in Figure 2, there was a significant quadratic effect of years of experience ($b = -1.3$, SE = 0.4, $t = -3.4$, $P = 0.001$). Specifically, according to our statistical model, effort–reward imbalance peaked at around 17 years of work experience as a consultant. We found no effect of sex ($b = -0.1$, SE = 0.1, $t = -1.8$, $P = 0.070$). These predictors together explained 15% of the total variance in the effort–reward ratio. For residents, we found that the effort–reward ratio increased linearly during training ($b = 0.6$, SE = 0.2, $t = 2.7$, $P = 0.010$). This model explained 17% of the total variance in the effort–reward ratio.

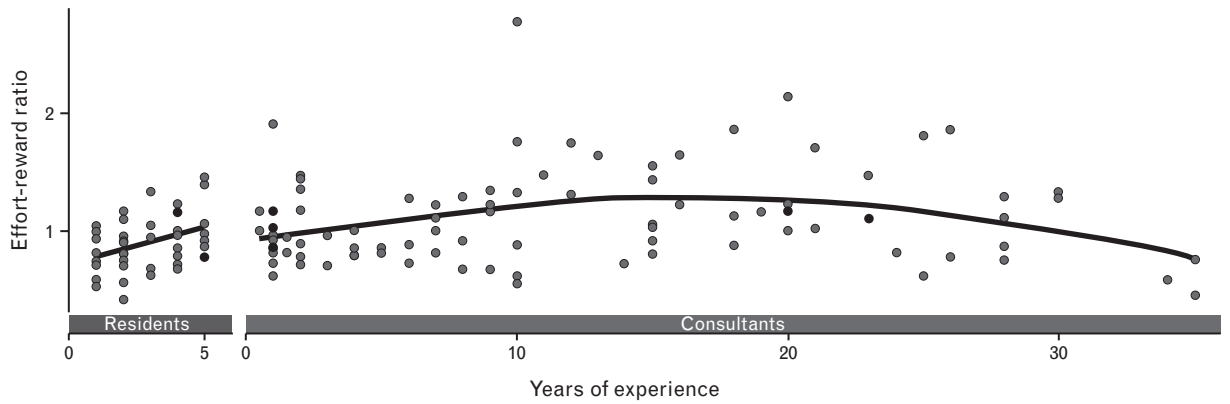
In separate analyses, we explored chronic stress originating from the home situation among consultants by using positive and negative HWI as outcome variables. In neither analysis did we find significant linear or quadratic effects of years of experience ($t < 1.6$, $P > 0.127$).

Discussion

To our knowledge, this is the first study examining hair cortisol concentration in anaesthesiologists. The mean values for HCC found in anaesthesiologists compare favourably with HCC in individuals suffering from chronic stressors reported in the literature.[12] However, in our sample, several consultants at the beginning and in the later phases of their career did show high concentrations of HCC, indicating chronic stress and allostatic load. Because of these individuals' high HCC values, we found a curvilinear relationship between HCC and years of experience in consultant anaesthesiologists. This finding suggested that, on average, chronic physiological stress was relatively high at the beginning of the career, decreased until approximately 11 years of work experience, and then increased again.

A curvilinear relationship between age and HCC has been previously reported in the literature. In a sample with ages ranging from 1 to 91 years, HCC was found to be higher in both young children and seniors.[29] However, a meta-analysis showed HCC to have only a small

Fig. 2 The effort–reward ratio of resident and consultant anaesthesiologists plotted against experience



positive linear correlation with age.[27] We found a significant curvilinear effect predicting 14% of the variance in a sample with a much smaller age range. For this reason, we believe our finding is not an artefact of commonly found relationships between age and HCC. Rather, we suggest that the effect we found is due to the variation in work experience. In line with this idea, another study found higher allostatic load when stressed towards the end of people's careers.[30]

In residents, the effort–reward ratio increased during the years of training, whereas in consultants we found a curvilinear relationship between effort–reward ratio and years of experience. Intriguingly, and in contrast with our findings regarding HCC, this source of perceived psychological stress peaked among mid-career consultants, when they had approximately 17 years of work experience as a consultant. Speculatively, this finding can be explained from the fact that mid-life may be a period in which one realises a sense of time limitation and a future that is not anymore one of unlimited possibilities.[14] However, people generally tend to become more positive when they transition into older adulthood due to prioritising different goals rather than seeking new experiences.[31] For this reason, it makes sense that effort–reward balance improves again among late-career anaesthesiologists.

We did not find the hypothesised relationship between trait emotional intelligence and HCC. Neither did we find a strong relationship between chronic physiological stress as indicated by HCC and psychological stress as indicated by effort–reward imbalance. The discrepancy between measures of physiological stress and psychological stress or personality seems to be counterintuitive. However, we should note that dissociations between biomarker measures of stress and self-reported measures of stress and/or personality are frequently reported in the literature.[12] An explanation could be that, in contrast to psychological stress, physiological stress does not have a positive or a negative evaluation *per se*. Indeed, some individuals psychologically thrive under stress, while others perish.[32] This idea is consistent with our earlier work, in which we found substantial individual differences in the way anaesthesiologists appraised work-related stressors.[33]

It might also be the case that some individuals with personality traits that predispose to experience of psychological stress have blunted cortisol responses.[34,35] Reasoning along these lines would mean that, in some individuals, a low HCC could indicate physiological stress as well. Other possible reasons for the discrepancy between physiological and psychological stress could be related to biases concerning questionnaires, such as recall bias and social desirability bias.[36] However this would mean that personalities with blunted cortisol responses and recall bias and/or social desirability bias should peak mid-career among anaesthesiologists, which seems implausible.

An important limitation of our study is that the relationship between HCC and the career phase depended on a small number of anaesthesiologists who had very high HCC. A second major limitation of the study is the lack of a control group, for example, a sample of physicians from another specialty and from the general population. Third, because our study has a cross-sectional design, we cannot make strict causal claims. Because of these limitations, our findings must be interpreted cautiously.

A strength of our study is that data obtained from the Dutch Anaesthesia Society showed that the conference attendees who participated in the study were typical of nonparticipating attendees. They were similar in consultant-to-resident ratio, and were similar in terms of the type of hospitals they worked at. However, the male:female ratio was different; relatively more female colleagues participated. This is probably because conference attendees could participate only if they had >3 cm of hair. Despite this, we find that as far as these variables are concerned, our study participants constitute a representative sample of attendees, which constituted a significant proportion of Dutch anaesthesiologists. A further strength of our study is that all samples and measurements were taken in the same short period of time and thus public major life events are eliminated or shared. Also, we examined the influence of home on work stress and by that made it plausible that the stress we measured was caused by work. Finally, LC-MS/MS, the method of HCC determinations which we used, is considered a gold standard because of its precision.[37]

Because health status is related to allostatic load, future studies should be aimed at quantifying allostatic load and subsequent mental and physiological health status in anaesthesiologists.[38,39] HCC should be used as one of the parameters of allostatic load and factors such as age, sex, career phase, perceived work stress and moderation by personality should be taken into account.

In summary, most anaesthesiologists show low physiological stress. However, some do show high hair cortisol concentrations, and these seem to occur to a greater extent late in anaesthesiologists' careers. The physiological stress response is not necessarily mirrored by psychological stress (e.g. due to an unfavourable effort–reward ratio). This finding suggests that the negative health consequences of chronic physiological stress might go unnoticed because they are not always accompanied by negatively perceived psychological stress.

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Presentation: none.

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