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SYMPTOM REPORTING DURING VOLUNTARY HYPERVENTILATION AND MENTAL LOAD: IMPLICATIONS FOR DIAGNOSING HYPERVENTILATION SYNDROME

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Abstract—Hyperventilation is considered an important factor in the production of a variety of somatic symptoms. This complex of symptoms is called the Hyperventilation Syndrome (HVS). Recognition of symptoms during the hyperventilation provocation test (HVPT) is a widely used criterion for diagnosing HVS. The validity of this criterion is tested in the present study.

Twenty-three patients suspected of HVS performed a HVPT (hyperventilation during 3 min) and a mental load task (Stroop Color Word Test; CWT). It appeared that about the same number of patients (61%) recognized symptoms during the HVPT as during the CWT (52%), despite severe hypocapnia in the first test and normocapnia in the second. Reporting of symptoms was significantly related to psychological state and trait measures (SCL-90 and STAI scores) and unrelated to the degree of hypocapnia. These data have far reaching consequences, as they not only undermine the validity of the HVPT, but also question the tenability of the concept of HVS.

INTRODUCTION

FOR A long time, investigators have been puzzled by the set of somatic symptoms, often mentioned by anxious patients, such as pounding of the heart, breathlessness, dizziness, fatigue and sweating. During recent decades hyperventilation has been suggested as a possible cause of these symptoms [1–9]. Hyperventilation is a physiological term, defined as ventilation in excess of metabolic requirements, implying a reduction of the PCO_2 in the blood. The concept of Hyperventilation Syndrome (HVS) refers to a set of somatic symptoms which are to a large extent caused by hyperventilation [10]. The concept implies (1) the presence of symptoms in daily life, (2) the occurrence of (a sufficient degree of) hyperventilation, and (3) a causal relationship between hyperventilation and the symptoms. Diagnostic procedures of HVS should encompass each of these three premisses.

To assess the first condition, relevant symptom questionnaires are available [9, 11, 12]. The second premiss is more difficult to assess. Hyperventilation may occur either chronically or in episodes. Chronic hyperventilation will become apparent from lowered arterial (or end tidal) PCO_2 values on repeated spot measurements, or from a decreased base excess (BE) of the blood [13]. Chronic hyperventilation has been found in 14% of HVS patients [13]. To detect episodic hyperventilation, the

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only adequate technique would be longterm ambulatory monitoring of PCO_2. Technical equipment for such longterm registration in daily life situations has only recently been developed [14], and is not generally available. Therefore, the occurrence of hyperventilation and its causal relationship to the somatic symptoms (the third premiss) is generally inferred from the results of a hyperventilation provocation test (HVPT). The test is considered positive if voluntary hyperventilation induces symptoms that are recognized by the patient as similar to those occurring in daily life. It is then assumed that hyperventilation brings about the symptoms in this patient.

Other methods and criteria for diagnosing HVS that have been proposed, proved to be no more valid than the criterion of symptom recognition. Some authors have stressed the importance of physiological indicators for hyperventilation [13, 15]. Hardonk and Beumer [16] stated that delayed recovery of end-tital PCO_2 following voluntary hyperventilation is characteristic of HVS patients. However, their study is suffering from serious methodological shortcomings and subsequent investigators have been unable to replicate their findings [17–19]. Freeman *et al.* [20] have proposed psychological challenge under hypnosis as a diagnostic aid. In their test the patient is confronted with personally relevant and problematic topics. The authors present some convincing examples of hyperventilation during the imagination of traumatic events. This test apparently demonstrates the tendency of a patient to respond with over-breathing in a stressful situation. Another test to demonstrate this tendency is the more standardized physical exercise test, applied by Gardner and co-workers [15]. However, neither the test–retest reliability nor the predictive value for the development of hyperventilation in daily life situations has as yet been established for either of these tests.

Even when hyperventilation is established in daily life situations, this does not imply that hyperventilation is the cause of the symptoms (the third premiss). This was recently demonstrated by Hibbert and Pilsbury [21]. They applied the method of longterm ambulatory measurement of transcutaneous PCO_2 ($PtcCO_2$) in patients with frequent panic attacks (attacks of somatic symptoms and subjective anxiety according to DSM-III-R criteria). Some patients showed considerable drops in the $PtcCO_2$ during panic attacks, while other patients had minor or no changes in $PtcCO_2$ during panic. If hyperventilation were an important symptom producing mechanism, we might expect qualitatively different sets of symptoms to manifest themselves in either kind of panic attack. However, such differences were not found.

The aim of the present study is to test the validity of symptom recognition during the HVPT as a diagnostic criterion for HVS. Our study replicates and extends a validation study by Roll [22]. His patients attended an emergency care unit because of chest pain without obvious organic cause. He considered the HVPT positive if at least three symptoms were recognized as being similar to the symptoms the patient experienced in daily life. This was the case in 44% of his patients. His patients also did a stressful mental load task (the Stroop Color Word Test; CWT). Although no hyperventilation occurred during this task, as many as 38% of the patients recognized three or more symptoms. These results indicate that the specificity of the HVPT is low as mental stress itself can reproduce symptoms without concomitant hypocapnia. They also suggest that, in many cases, symptom recognition and

reporting during the provocation test is not due to a lowering of arterial PCO_2, but to aspecific factors, such as the stressfulness of the procedure. These data have far reaching consequences, as they undermine the validity of the provocation test. If the results are replicated, one will have to conclude that many patients have been misdiagnosed in the past (false positives).

Roll used the numerical diagnostic criterion of 'at least three recognized symptoms'. In our replication study we added a second diagnostic criterion of 'overall recognition'. This is generally considered more valid, because the conclusion of recognition seems most justified when the patient considers the symptoms in general as being similar to the symptoms occurring in normal life.

It seems plausible that the role of hyperventilation is not equally important for all symptoms mentioned by HVS patients. We tackled this issue by singling out three categories of symptoms: (a) symptoms of the 'HVS in the restricted sense', defined by Weimann as symptoms that are reliably produced by voluntary hyperventilation, both in HVS patients and healthy subjects [23]. According to Weimann, symptoms of this category are clearly related to the pathophysiological changes induced by hyperventilation. However, the presence of HVS-symptoms in the restricted sense does not necessarily imply hyperventilation, as these symptoms may also be induced by other physiological mechanisms. (b) A category of 'general arousal' symptoms, such as tachycardia, pounding of the heart, sweating and fatigue. These symptoms are frequently reported by HVS patients, but the pathophysiological relation to hyperventilation is less clear. (c) A category of 'dummy' symptoms, such as low back pain and stinging eyes, which are unlikely to be produced by hyperventilation or by physiological arousal in general. This category of dummy symptom is added to investigate whether there is a general bias towards symptoms reporting.

Finally, we investigated whether the experience of symptoms during hyperventilation and mental load is related to age, duration of illness, tension experienced during the experimental phases, trait anxiety, agoraphobia and depression.

METHOD

Subjects

Subjects were consecutive out-patients, referred to us by medical specialists and General Practitioners on the basis of signs and symptoms suggesting HVS. From a total of 34 referred patients, three were excluded because they experienced less than four symptoms a week; four were excluded because of insufficient command of the Dutch language; and four patients refused to participate. The final sample comprised 23 subjects; 12 female and 11 male, ranging in age from 16 to 66 yr, with a mean of 42.3 yr.

Procedures

Each patient participated in both a hyperventilation and a stressful mental load task. The order of conditions was randomly varied, with 20 min interval between tasks. Prior to the experimental phase, the patient was interviewed and requested to complete three questionnaires: the Bodily Sensations Questionnaire (BSQ), the State Trait Anxiety Inventory (STAI) and the Symptom Checklist (SCL-90).

During the hyperventilation provocation test (HVPT) the patient sat in a reclining chair. After breathing normally for 3 min (baseline period), he or she was instructed to breathe as rapidly and as deeply as possible. Additional instructions were given to keep $PetCO_2$ below 20 mmHg for at least 1 min. After 3 min of hyperventilation the patient was instructed to return to normal breathing. Registrations were continued for a further 3 min (recovery phase).

Mental stress was induced by a video-version of the Stroop Color Word Test (CWT) [24]. For 10 min the words 'red', 'blue', 'green' and 'yellow' are randomly presented in incongruous colours, with a rate of about 28 words per min. For example, the word red is presented in green letters. The subject has to indicate the colour of the letters on an answer sheet (green, in this case). The CWT was preceded by a baseline period, and followed by a recovery period of 3 min duration each.

During the HVPT and CWT the patient was attached to a capnograph for continuous registration of tidal PCO_2 and respiratory rate.

Measures

Bodily Sensations Questionnaire (BSQ) [9]. The BSQ lists 32 somatic sensations often mentioned by HVS patients. These symptoms were divided into the following categories (see Table 1): symptoms belonging to the 'HVS in the restricted sense' (nine items), 'respiratory symptoms' (five items), 'psychological symptoms' (three items) and a rest category of 'general arousal symptoms' (15 items). For this study six dummy symptoms were added, i.e. sensations rarely associated with hyperventilation. The total BSQ score thus includes 38 items. When statistical tests were applied to specific symptoms, the categories of dummy symptoms, symptoms of the HVS in the restricted sense, and general arousal symptoms were used; they seemed most adequate to test the validity of the HVPT.

The BSQ has a trait and a state version. The trait version was completed by the subject during pretest assessment. It inquires after the occurrence of symptoms during the past month. Ratings are made on a four-point scale (range 0–3) comprising the categories 'did not occur', 'one or more times a month', 'one

TABLE 1.—SYMPTOMS OF THE BODILY SENSATIONS QUESTIONNAIRE AND SIX DUMMY SYMPTOMS

HVS in the restricted sense
Paresthesias
Muscle cramps
Shivering
Muscle stiffness
Cold hands or feet
Stiffness round the mouth
Trembling
Dizziness
Blurred vision
Respiratory symptoms
Inability to take a deep breath
Tightness around the chest
Lump in throat
Sudden fast or deep breathing
Breathlessness
Psychological symptoms
Unrest, tension
Confusion or feelings of unreality
Anxiety, panic
General arousal symptoms
Rapid heartbeat
Pounding of the heart
Irregular heartbeat
Chest pain
Abdominal pain or cramps
Hot flashes
Warm feeling in head
Bloated stomach
Tiredness
Headaches
Fear of fainting
Fainting
Sweating
Sudden feeling of muscle weakness
Nausea
Dummy symptoms
Low back pain
Aching joints
Heartburn
Itching
Stinging eyes
Trembling eyelids

or more times a week', and 'daily'. The total score on this questionnaire will be referred to as the spontaneous symptom score. The state version of the BSQ was completed directly after the HVPT and the CWT; it consists of two parts. Firstly, it enquires which (if any) of the 38 symptoms were experienced during the test. Items were scored using a three-point format: not, weak, or strong (range 0–2). The total score on this scale is referred to as the induced symptom score. Secondly, it enquires whether the induced symptoms were recognized, scored as yes (1) or no (0). The total number of recognized symptoms gave rise to the recognized symptom scores. At the start of the experiment patients were asked for symptoms already present. Few people reported pretest symptoms. These symptoms were skipped in the post-test questionnaires.

State Trait Anxiety Inventory (STAI) [25]. The Dutch version of this measure of general anxiety has satisfactory reliability and validity [26]. Only the trait version was used in the present study.

Symptom Checklist-90 (SCL-90) [27, 28]. This questionnaire is a widely used and well validated self-report inventory measuring psychopathology. In the present study only the subscales agoraphobia, anxiety and depression were used.

Tension scale. Subjective feelings of tension were assessed by means of a visual analogue scale (range 0–100). Pretest values were determined shortly before each test, while test values were assessed retrospectively after the HVPT and the CWT.

Physiological measurements. Tidal PCO_2 and respiratory rate (RR) were continuously registered during the HVPT and the CWT by means of a Godaert capnograph. End-tidal PCO_2 ($PetCO_2$) and RR were averaged over the last 30 s of each baseline, task and recovery period. To determine $PetCO_2$, only cycles with an alveolar plateau were used.

Diagnostic criteria

Recognition of symptoms during the HVPT and the CWT was determined in two ways. Firstly, the test was considered positive if at least four symptoms were recognized. Contrary to Roll, we used four instead of three symptoms as a limit value, since our somatic sensations questionnaire contains more items than Roll's. Secondly, the criterion of overall recognition was used, which refers to the question 'Do you in general consider the symptoms you have experienced during this test as similar to the symptoms you suffer from in everyday life?'

Statistical analyses

Differences between the HVPT and the CWT were tested by means of paired t-tests or Wilcoxon tests. Pearson product–moment correlation coefficients were used to determine the relationships between the symptom scores (spontaneous, induced and recognized symptom scores) and other questionnaire data (Tension Scale, SCL-90 and STAI). Two-tailed tests for significance were applied, with the significance level set at $p < 0.05$.

RESULTS

Manipulation checks

Mean scores, reflecting change in $PetCO_2$ from baseline to task and recovery periods, confirmed that hypocapnia was induced during the HVPT, but not during the CWT (see Fig. 1A). For the HVPT, mean $PetCO_2$ during baseline, task and recovery was 39.2 (SD = 4.9), 16.4 (SD = 2.7) and 26.6 (SD = 5.3) mmHg respectively. Corresponding values for the CWT were 39.2 (SD = 6.0), 38.0 (SD = 5.5) and 38.2 (SD = 5.6) mmHg. Although the mean decrease of 1.2 mmHg during the CWT test was statistically significant ($t = 2.26$, $p = 0.035$), it is evident that such modest changes can hardly produce symptoms (reduction of the $PetCO_2$ during the CWT never exceeded 5 mmHg).

Mean values for respiratory rate during baseline, task and recovery of the HVPT were 16.6 (SD = 4.3), 34.5 (SD = 9.1) and 15.4 (SD = 3.6) cycles/min. respectively. For the CWT these values were 15.9 (SD = 4.2), 17.4 (SD = 4.6) and 14.2 (SD = 4.1) cycles/min.

Figure 1B shows the pretest and test levels of mean Tension Score. Subjectively experienced tension increased significantly during the HVPT ($t = 2.64$, $p = 0.015$) and during the CWT ($t = 2.47$, $p = 0.022$), while no significant differences were found

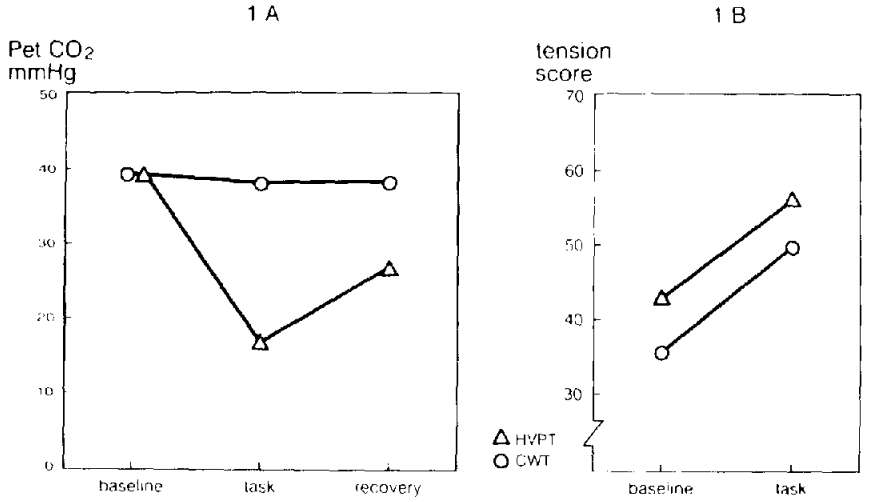

FIG. 1. A: Mean end-tidal PCO_2 ($PetCO_2$) during baseline, task and recovery periods of the Hyperventilation Provocation Test (HVPT) and Stroop Color Word Test (CWT). B: Mean Tension Scores for baseline and task periods of the HVPT and CWT.

between tasks. Thus, on the average, patients considered the HVPT and the CWT equally stressful.

Induced and recognized symptoms

Table II summarizes mean scores for each of the symptom categories. The total score on each scale has been divided by the number of items to make them comparable. As can be seen, the HVPT brought about more induced and recognized symptoms than did the CWT. This effect was most pronounced for the HVS in the restricted sense but also significant for the general arousal symptoms. Dummy symptoms were hardly induced in either HVPT or CWT.

Diagnostic outcomes

In contrast to the above findings, referring to the number of symptoms, the diagnostic outcomes point to similarity between the two tests. When the diagnosis

TABLE II.—INDUCED AND RECOGNIZED SYMPTOM SCORES FOR THE HYPERVENTILATION PROVOCATION TEST (HVPT) AND THE STROOP COLOR WORD TEST (CWT)

	Mean score		Difference between tests	
	HVPT	CWT	Z	p
Induced symptom score				
Total	0.44	0.22	3.4	0.001
HVS in the restricted sense	0.65	0.15	3.9	0.000
General arousal	0.35	0.20	2.4	0.02
Dummy	0.04	0.05	0.3	0.75
Recognized symptom score				
Total	0.22	0.16	2.3	0.02
HVS in the restricted sense	0.28	0.12	3.3	0.001
General arousal	0.21	0.14	2.1	0.04
Dummy	0.03	0.04	0.8	0.42

Possible range: induced symptoms 0-2; recognized symptoms 0-1.

HVS was based on the criterion of at least four recognized symptoms during the HVPT, 70% of the patients in our study were positive. However, as can be seen in Table IIIA, an equal percentage of patients (70%) recognized four or more symptoms during the CWT.

Results for the diagnosis based on the criterion of overall recognition are presented in Table IIIB. Positive on the HVPT were 14 out of 23 patients (61%). They would be considered as HVS patients on the basis of the classical diagnostic criterion. As many as nine out of these 14 patients (65%) may be considered as false positives: they also recognized symptoms during the non-hyperventilation task. Only four of the positively diagnosed HVS patients (29%) 'behaved' as could justifiably be expected according to the HVS concept.

Correlational data

Table IV presents the relationships between scores for (spontaneous, induced and recognized) symptoms on the one hand and age, duration of illness and psychological measures on the other. Duration of illness correlated negatively with number of recognized symptoms during HVPT: the longer the illness, the fewer symptoms were recognized. Age was not related to symptom scores. Tension scores were positively related to the number of induced and recognized symptoms, though not always significantly. The correlation coefficients were higher for the CWT than for the HVPT. Positive and often significant correlations were also found between bodily symptom scores and measures of trait anxiety, agoraphobia and depression (STAI and SCL-90 scores). Thus, the more tense patients were during the test, and the more anxious, agoraphobic and depressed they were in general, the more symptoms they experienced in everyday life and the experimental situations. The relationship between bodily symptoms and psychological measures appeared to be particularly clear for the general arousal symptoms. Symptoms of the HVS in the restricted sense

TABLE III. —NUMBER OF PATIENTS WHO RECOGNIZE SYMPTOMS DURING THE HYPERVENTILATION PROVOCATION TEST (HVPT) AND DURING THE STROOP COLOR WORD TEST (CWT)

TABLE IIIA.—SYMPTOM RECOGNITION ON THE BASIS OF THE CRITERION OF 'AT LEAST FOUR SYMPTOMS RECOGNIZED'

		Number of Symptoms Recognized CWT		
		<4	$\geqslant 4$	Total
HVPT	<4	4	3	7 (30%)
	$\geqslant 4$	3	13	16 (70%)
	Total	7 (30%)	16 (70%)	$N = 23$ (100%)

TABLE IIIB.—REPRESENTS THE CRITERION OF 'OVERALL RECOGNITION'

		Overall recognition CWT			
		NO	YES	?	Total
HVPT	NO	5	3	–	8 (35%)
	YES	4	9	1	14 (61%)
	?	1	—	—	1 (4%)
	Total	10 (44%)	12 (52%)	1 (4%)	$N = 23$ (100%)

TABLE IV.—PEARSON PRODUCT MOMENT CORRELATION COEFFICIENTS FOR THE RELATION BETWEEN SYMPTOM SCORES AND OTHER VARIABLES ($N = 23$)

	Spontaneous symptoms	Induced symptoms HVPT	Induced symptoms CWT	Recognized symptoms HVPT	Recognized symptoms CWT
Age	—	—	—	—	
Duration of illness	—	—	—	−0.47*	—
Spontaneous symptoms	×	—	—	0.55**	0.50*
Tension scores					
baseline	×	—	0.61**	0.47*	0.64*
task	×	0.42*	0.60**		0.66*
SCL-90					
Agoraphobia	0.51*	—	0.47*	0.57**	0.50*
Anxiety	0.52**		0.43*	0.54**	0.52*
Depression	0.46*	0.49*	0.51*	0.53**	0.50*
STAI (trait)	0.51*	0.60**	0.49*	0.57**	0.43*

— Not significant; × not relevant; *$p < 0.05$ (two-tailed); **$p < 0.01$; SCL-90: Symptom Check List-90; STAI: State-Trait Anxiety Inventory.

and dummy symptoms were not significanly related to psychological state and trait measures.†

Correlation coefficients were also computed for the relationships between respiratory measures and induced and recognized symptom scores. Of the 72 computed correlation coefficients (two respiratory variables × three periods × 12 symptom scores) only one was significant: the lower the $PetCO_2$ during the recovery phase of the HVPT, the higher the number of induced symptoms ($r = 0.44$, $p < 0.05$). Thus, symptom reporting during the HVPT and the CWT was largely independent of respiratory rate and end-tidal PCO_2 levels. This conclusion holds for each category of the Bodily Symptom Questionnaire. The absence of a significant relationship between on the one hand reported and recognized symptoms and on the other hand $PetCO_2$ levels, is especially remarkable for symptoms of the HVS in the restricted sense.

DISCUSSION

Rolls' findings were replicated in this study. This means that once again, and in a different setting, recognition of symptoms during the hyperventilation provocation test proved to be invalid in diagnosing Hyperventilation Syndrome. Recognition of symptoms occurred nearly as often during a stressful mental load task without concomitant hypocapnia as during voluntary hyperventilation.

Few other validation studies have been reported. Two studies have been published comparing the HVPT and a control condition on the number of symptoms occurring during these tests (instead of an overall recognition). They concern non-patient samples. Svebak and Grossman [29] compared reactions to a HVPT and a video game, the latter with or without threat of an aversive shock. The number of recognized symptoms was significantly larger in the hyperventilation condition that in the non hyperventilation task, but the difference in absolte magnitude was small. Moreover, the number of recognized symptoms was also larger in the threat than in the no-threat condition of the video game (both without hypocapnia), indicating

†The r- and p-values for the BSQ-subscales can be obtained from first author.

that psychological manipulation induced differences similar to manipulation of PCO_2. These results led the authors to conclude that 'a sizeable portion of the presenting complaints could not be explained as specifically due to hyperventilation' (p. 333).

A study which seems to support the validity of the HVPT is a study by Huey and West [30]. The compared responses to the HVPT with responses to a control condition, during which the subject breathes as deeply and as rapidly as during the HVPT, but this time hypocapnia is prevented by the inhalation of CO_2-enriched air (Normocapnic Overbreathing Test). From a student sample a group of 'likely hyperventilators' and a group of 'unlikely hyperventilators' were selected on the basis of their responses on a symptom questionnaire. Likely hyperventilators experienced more symptoms than unlikely hyperventilators during the HVPT while there was no difference between groups during the NOT. Another finding confirming the validity of the HVPT, at least at first glance, was the fact that both tests differed in number of hyperventilation-related symptoms, but not in the number of dummy symptoms. However, this argument is open to criticism. In both our study and the study of Huey and West, dummy symptoms were hardly produced during either test, making the absence of a difference less meaningful.

In our study we made a distinction between symptoms of the HVS in the restricted sense and general arousal symptoms. A specific effect of hyperventilation on symptom reporting might be concluded from our data for the symptoms of the HVS in the restricted sense. Symptoms of this category were more often induced during hyperventilation, and—in contrast to the general arousal symptoms—not related to psychological trait and state measures. One should not, however, attach too much meaning to these findings. Firstly, symptoms of this category were produced significantly more often during the HVPT than during the control condition, but the same applied to the general arousal symptoms. This seems to indicate that the HVPT leads to more symptoms in general. Secondly, the difference between both categories for induced symptoms is virtually absent for recognized symptoms. Thirdly, the symptoms of the HVS in the restricted sense comprise only nine symptoms. The majority of symptoms mentioned by 'HVS patients', both in daily life and during the tests, belong to other categories, mainly the category of 15 'general arousal' symptoms. The HVPT, therefore, seems to provoke many symptoms that are unrelated to hyperventilation.

What remains to be explained is a general tendency of the HVPT to induce more symptoms than the Stroop-test. The hypocapnic condition during the HVPT cannot exhaustively explain this difference. The most obvious explanation is that the procedure of the HVPT was considered more stressful. This is, however, contradicted by the results of our tension scores. Another explanation concerns the focus of attention, which is more likely to be directed towards bodily sensations during the HVPT, and towards task performance during the CWT. Plausible, too, are explanations which include expectancies (from patients and researcher). More research into the problem of symptom reporting during (voluntary) hyperventilation directed towards these factors seems indicated. Their importance is suggested by this study.

After discussing the details concerning the number of symptoms induced and recognized during both tests, we will return to the main item of this study, namely

overall recognition as the basis of a diagnosis HVS. Overall recognition was practically similar in both tests. From the general conclusion of this study it seems inevitable that the role of hyperventilation has been grossly overestimated so far. This negative outcome not only undermines the validity of the HVPT as a diagnostic procedure, but also raises doubt on the value of the HVS as a clinical syndrome. Up until today, the mere fact that in some patients symptoms could be reproduced by the provocation test, was an important reason for the interest in hyperventilation as a symptom producing mechanism and for the belief in the HVS as a scientifically and clinically valuable entity. Possibly, spontaneous hyperventilation is but an epiphenomenon of subjective tension, anxiety or panic, comparable to other signs of physiological arousal, such as tachycardia, which also frequently occurs in panic [31]. The term Hyperventilation Syndrome would then no longer make sense. The procedure of the HVPT may still be a viable therapeutic technique for exposure to feared bodily sensations.

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