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Sleep-related breathing disorders in facioscapulohumeral dystrophy

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Abstract

Purpose Severe manifestations of facioscapulohumeral dystrophy (FSHD) may be associated with sleep-disordered breathing (SDB), including obstructive sleep apnea (OSA) and nocturnal hypoventilation (NH), but prevalence data are scarce. In patients with respiratory muscle weakness, detection of NH can be facilitated by transcutaneous capnometry, but respective data derived from FSHD patients have not yet been published.

Methods We collected sleep studies and capnometry recordings from 31 adult patients with genetically confirmed FSHD who were admitted to our sleep laboratory for first-ever evaluation of sleep-related breathing. Indications for admission included non-restorative sleep, morning headache, or excessive daytime sleepiness. In addition, sleep studies were initiated if symptoms or signs of respiratory muscle weakness were present. Thirty-one subjects with insomnia served as controls for comparison of respiratory measures during sleep.

Results In the FSHD group, 17/31 (55%) patients showed OSA and 8 (26%) had NH. NH would have been missed in 7/8 patients if only oximetry criteria of hypoventilation had been applied. Capnography results were correlated with disease severity as reflected by the Clinical Severity Score (CSS). Non-invasive ventilation (NIV) was started in 6 patients with NH and 3 individuals with OSA. Nocturnal continuous positive airway pressure was administered to 2 patients, and positional therapy was sufficient in 4 individuals. In patients initiated on NIV, nocturnal gas exchange already improved in the first night of treatment.

Conclusions SDB is common in adult patients with FSHD complaining of sleep-related symptoms. It may comprise OSA, NH, and most often, the combination of both. Sleep-related hypercapnia is associated with disease severity. Transcutaneous capnometry is superior to pulse oximetry for detection of NH.

Keywords Fascioscapulohumeral dystrophy · Sleep-disordered breathing · Nocturnal hypoventilation · Non-invasive ventilation · Transcutaneous capnometry

Abbreviations

AHI	Apnea-Hypopnea Index
BMI	Body mass index
CO_2	Carbon dioxide
CPAP	Continuous positive airway pressure
CSS	Clinical Severity Scale
EDS	Excessive daytime sleepiness
ESS	Epworth Sleepiness Scale
FSHD	Facioscapulohumeral dystrophy
FSS	Fatigue Severity Scale
NH	Nocturnal hypoventilation
NIV	Non-invasive ventilation
NS	Not significant
ODI	Oxygen desaturation index
OSA	Obstructive sleep apnea
PAP	Positive airway pressure
pCO_2	Carbon dioxide pressure
PSG	Polysomnography
PSQI	Pittsburg Sleep Quality Index
$p_{tc}CO_2$	Transcutaneous carbon dioxide tension

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REM	Rapid eye movement
SD	Standard deviation
SDB	Sleep-disordered breathing
SpO_2	Oxygen saturation
TC	Transcutaneous capnometry

Introduction

Facioscapulohumeral dystrophy (FSHD; Online Mendelian Inheritance in Man® #158900) is an autosomal dominant–inherited myopathy that is characterized by progressive atrophy and weakness of a highly selective set of muscle groups [1, 2]. Disease onset is usually in the second decade of life, and facial muscles are involved first. With disease progression, weakness also involves the shoulder and upper arm muscles (deltoid, scapular fixators, pectoralis major, and biceps), tibialis anterior muscles, and abdominal muscles. In a subset of patients, paravertebral muscles may be affected leading to a characteristic "bent spine" phenotype [3]. FSHD is one of the most common muscular dystrophies, with prevalence up to 1:30,000 [4]. FSHD1 and FSHD2 are distinguished based on the specific molecular genetic cause. Patients with FSHD1 (95% of cases) carry a chromosomal rearrangement within the subtelomeric region of chromosome 4q35 [5, 6], while in FSHD2, there is a loss-of-function mutation in the SMCHD1 gene [7].

Neurological impairment in FSHD can be highly variable, ranging from mild forms where the patient can sometimes be unaware of the disease to severe manifestation in wheelchair-bound individuals. Significant involvement of the respiratory muscles and sleep-disordered breathing (SDB) are common in the dystrophinopathies [8, 9], myotonic dystrophy type 1 [10], and certain subtypes of limb-girdle muscular dystrophies [11, 12]. In FSHD, very few studies have systematically evaluated the prevalence and clinical impact of SDB, which usually manifests as either nocturnal hypoventilation (NH) or obstructive sleep apnea (OSA) [13].

Respiratory involvement has been considered a rare manifestation of FSHD, associated with longstanding or severe disease, especially if spine deformities, significant leg weakness, or wheelchair dependency are present. According to a previous study, only 1% of patients with FSHD require non-invasive ventilation (NIV) [14] but more recent reports suggest that nocturnal ventilatory support may be indicated in a larger proportion of patients [15, 16]. Della Marca et al. found isolated OSA, rapid eye movement (REM) sleep-associated desaturation without apneas or a mixed pattern of SDB in 39% of patients ($n = 51$), and positive airway pressure (PAP) treatment was initiated in 6% [16]. However, hypoventilation was only defined as oxygen desaturation without flow limitation, and nocturnal capnometry was not performed in that study. This issue was addressed in more detail by another study in 94 patients that reported spirometric data along with overnight pulse oximetry and nocturnal arterial blood gases [15]. Seventeen patients (18.1%) were diagnosed with SDB, including 13 with NH, two with OSA and two with combined SDB, and up to 14% were started on NIV. In addition, 38.3% of patients showed significant respiratory muscle weakness. These values far exceed those reported in previous studies.

Nocturnal transcutaneous capnometry (TC) has been shown to be much more sensitive than pulse oximetry for detecting NH in patients with neuromuscular disorders and may help to early identify patients in whom NIV is indicated [17–19]. In order to evaluate suspected SDB in FSHD, we collected comprehensive capnometry and sleep study data along with clinical characteristics in a cohort of adult patients and evaluated the overnight effects of NIV on sleep architecture and self-reported sleep quality.

Material and methods

Patients

Between 1 January 2008 and 28 April 2018, 31 non-ventilated patients with genetically confirmed FSHD1 were consecutively admitted to our sleep laboratory for first-ever evaluation of sleep-related breathing. Indications for hospital admission included sleep-related complaints such as excessive daytime sleepiness, non-restorative sleep, or morning headache. Sleep studies were also initiated if signs and symptoms of respiratory muscle weakness were present (forced vital capacity < 70% of predicted, exertional dyspnea, orthopnea). Thirty-one subjects with insomnia from our database were matched for gender, age, and body mass index (BMI) and served as a control group; all control subjects were free of any neuromuscular or other neurological diseases.

Sleep studies

Diagnostic sleep studies comprised either full polysomnography (PSG; Nihon Kohden, Rosbach, Germany) or cardiorespiratory polygraphy (Weinmann, Hamburg, Germany), both of which were performed and evaluated according to standard recommendations [20]. Sleep stage distribution and sleep-associated events were manually scored from PSG recordings. Documentation of respiratory measures included the apnea-hypopnea index (AHI), oxygen

desaturation index (ODI), and oxygen saturation (SpO_2). Sleep apnea was defined as an AHI exceeding 5/h [21]. An apnea was classified as obstructive when nasal flow amplitude dropped by ≥ 90% for 10 s or more with thoracoabdominal effort preserved. A central apnea was scored when the flow amplitude decreased by ≥ 90% for ≥ 10 s with no respiratory effort during the event. If the latter re-occurred during an initially central apnea, the event was categorized as a mixed type apnea. Hypopneas were scored when oronasal flow was reduced by 30% at least for ≥ 10 s accompanied by oxygen desaturation (≥ 3%) [18, 22]. TC (Sentec, Therwil, Switzerland) was performed with each PSG or polygraphy. Nocturnal hypercapnia was diagnosed when transcutaneous carbon dioxide tension ($p_{tc}CO_2$) during sleep exceeded 50 mmHg or increased by more than 10 mmHg from the awake supine value [23]. For comparison of methods, hypoventilation was also defined based on oximetry parameters (e.g., as $SpO_2 \leq 88\%$ for at least five consecutive minutes [24], as mean nocturnal $SpO_2 < 90\%$ [25], or as $SpO_2 < 90\%$ during ≥ 10% of the recording time [26]). Early morning capillary blood gases were drawn from the arterialized earlobe. Daytime hypercapnia was defined as $pCO_2 > 45$ mmHg. In patients with FSHD who were started on positive airway pressure (PAP) or NIV, we evaluated short-term treatment effects on sleep and ventilation outcomes in the first night of treatment.

Clinical assessment

From clinical records, we extracted anthropometric data, overall neurological status, and detailed information on sleep-related symptoms. Neurological impairment was categorized according to the Clinical Severity Scale (CSS), which reflects weakness in various muscle groups, including the spread of symptoms to pelvic and proximal leg muscles, unequivocally indicating disease progression [6]. The CSS score ranges from 0.5 ("facial weakness") to 5 ("wheelchair bound"). Sleep-related symptoms were self-reported by patients and control subjects using the Epworth Sleepiness Scale (ESS) [27] and the Pittsburgh Sleep Quality Index (PSQI) [28]. The ESS rates sleep propensity in everyday situations. Scores > 10 are considered to indicate excessive daytime sleepiness (EDS). The PSQI covers several aspects of sleep quality during the last 4 weeks including sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, daytime dysfunction and overall sleep quality. A PSQI global score of > 5 is considered indicative of meaningful sleep quality impairment. Self-reported fatigue was assessed using the Fatigue Severity Scale (FSS), with scores > 4 indicating significant fatigue [29].

Statistical methods

Statistical data analysis was performed using SPSS® v25.0 (IBM Inc., Armonk, NY). Normally distributed data are presented as mean ± standard deviation, and the *t* test for independent samples or the paired *t* test was applied as appropriate. For non-parametric data, the Mann-Whitney *U* test or the Kruskal-Wallis test was used. Categorical variables were compared using the χ^2 test. For associations between continuous variables, Pearson's correlation coefficient was applied. Bonferroni's correction was used for multiple testing. *P* values < 0.05 were considered statistically significant.

Results

Demographics and disease characteristics

Genetically, all patients had FSHD1. Table 1 summarizes baseline clinical and demographic data for patients and controls; matching meant that there were no significant between-group differences regarding sex, age, and BMI. None of the patients or controls had previously been established on NIV or continuous positive airway pressure (CPAP) treatment. In patients with FSHD, the CSS score did not correlate with age or BMI, and the CSS score, age, and BMI did not differ significantly between women and men. PSG was performed in 28 patients and all controls, and polygraphy was conducted in three patients. Capnometric data were available in all 31 FSHD patients but not in the control subjects.

Sleep-related symptoms

The ESS and FSS sum score was available for all patients and controls, whereas only 16 of the patients with FSHD fully completed the PSQI. The majority of patients with FSHD and control subjects reported nocturnal sleep disturbances and non-restorative sleep. Self-reported sleep quality (based on the PSQI global score) was severely reduced in both FSHD patients and controls. In control subjects, sleep quality was worse than in FSHD patients reflecting that this group comprised patients with chronic insomnia. Self-reported daytime sleepiness (based on the ESS sum score) was similar in both groups. The mean FSS score was similar between groups, but significant fatigue was reported by more patients with FSHD than control subjects (Table 1).

Sleep-related breathing

Sleep apnea, defined as AHI > 5/h, was present in over half of the patients with FSHD but < 10% of control subjects ($p < 0.001$) (Table 1). The most common type of SDB was OSA, but a significant proportion of patients had NH

Table 1 Clinical and demographic data, self-reported symptoms, and respiratory parameters in FSHD patients and control subjects

	FSHD patients ($n = 31$)	Control subjects ($n = 31$)	p value
Clinical characteristics			
Age (years)	53.7 ± 16.7 (18–79)	53.4 ± 11.7 (20–70)	NS
Female (% patients)	40.0	40.0	NS
BMI (kg/m^2)	24.6 ± 4.3 (15–33)	25.9 ± 2.7 (17–28)	NS
CSS score	3 ± 0.7 (1–5)	–	–
Self-reported symptoms			
ESS sum score	7.1 ± 4.6 (0–19)	6.7 ± 3.7 (0–12)	NS
ESS sum score > 10 (% patients)	17.2%	16.1%	NS
PSQI global score	8.1 ± 4.3 (−16)	12.4 ± 4.3 (2–20)	*< 0.05*
PSQI global score ≥ 5 (% patients)	66.7	96.8	*0.01*
FSS score	4.4 ± 1.3 (3–7)	4.7 ± 1.5 (2–7)	NS
FSS score > 4 (% patients)	57.1	35.5	NS
Respiratory parameters			
AHI (/h)	8.9 ± 10.1 (0–47)	1.5 ± 1.7 (0–7)	*< 0.001*
AHI > 5/h (% patients)	54.8	6.5	*< 0.05*
ODI (/h)	8.0 ± 12.3 (0–67)	1.5 ± 1.3 (0–4)	*< 0.01*
Minimum SpO_2 (%)	85.5 ± 8.4 (51–95)	88.5 ± 4.8 (80–96)	NS
Mean SpO_2 (%)	95.0 ± 3.2 (83–98)	94.2 ± 1.5 (90–98)	NS
Time with SpO_2 < 90% (min)	19.1 ± 78.5 (0–409)	0.2 ± 0.34 (0–2)	*< 0.05*
Mean $p_{tc}CO_2$ (mmHg)	42.3 ± 6.1	–	–
Maximum $p_{tc}CO_2$ (mmHg)	47.1 ± 6.9	–	–
$\Delta ptcCO_2$ (mmHg)	6.5 ± 3.5	–	–

p values below 0.05 are shown in italic format

Values are depicted as mean and standard deviation (ranges in brackets)

AHI, apnea-hypopnea index; *BMI*, body mass index; *CSS*, Clinical Severity Scale; *ESS*, Epworth Sleepiness Scale; *FSS*, Fatigue Severity Scale; *NS*, not statistically significant; *ODI*, oxygen desaturation index; *PSQI*, Pittsburgh Sleep Quality Index; $p_{tc}CO_2$, transcutaneous carbon dioxide tension; $\Delta p_{tc}CO_2$, difference between baseline and maximum $p_{tc}CO_2$; SpO_2, peripheral oxygen saturation

(Fig. 1). OSA and NH coincided in 7 patients, meaning that all but one of those with NH also had OSA. The AHI was > 15/h in 7 patients with FSHD (22.6%) and none of the controls ($p < 0.01$).

Mean AHI and mean ODI were both significantly higher in the FSHD group versus controls (Table 1). In the FSHD group, the AHI ranged between 0.0 and 47.2/h did not significantly differ between genders and was slightly correlated

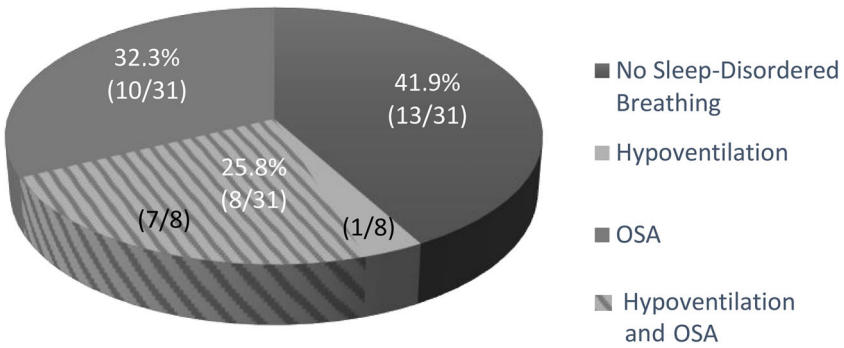

Fig. 1 Types and rate of sleep-disordered breathing in patients with FSHD. OSA, obstructive sleep apnea. OSA and hypoventilation coincided in 7 patients, i.e., all but one of the patients with nocturnal with hypoventilation also had OSA

with age ($r = 0.34$, $p = 0.06$) and BMI ($r = 0.33$, $p = 0.08$). The central apnea index (CAI) was < 5/h in all subjects.

Early morning, capillary blood gases showed hypercapnia (carbon dioxide pressure (pCO_2) > 45 mmHg) in one FSHD patient with NH. Using diagnostic thresholds of $SpO_2 \leq 88\%$ for ≥ 5 consecutive minutes, mean $SpO_2 < 90\%$, and $SpO_2 < 90\%$ for ≥ 10% of recording time pulse oximetry would have missed NH in 5/8, 6/8, and 7/8 patients, respectively. Mean and maximum $p_{tc}CO_2$ were both significantly correlated with disease severity as reflected by the CSS score (Fig. 2).

Nocturnal NIV was successfully initiated in six out of eight individuals with NH (including the one patient with daytime hypercapnia) and in three patients with OSA. Expiratory pressures used for successful treatment of NH by NIV were 7 ± 1 (minimum) and 10 ± 2 cmH_2O (maximum), with inspiratory pressure of 20 cmH_2O. PAP therapy was started in two patients (expiratory pressure used, 6–16 cmH_2O), and positional therapy was sufficient in four individuals.

Sleep outcomes

Subgroup analysis showed that neither OSA nor NH was associated with impaired sleep architecture or reduced sleep efficiency during diagnostic sleep studies in FSHD patients with versus without SDB (Table 2). In six patients who were started on NIV, short-term effects on gas exchange and objective sleep quality were evaluated in the first night of treatment; both ventilation and oxygenation were normalized in all patients. Mean AHI decreased from 21.9 ± 13.1/h to 3.0 ± 2.8/h ($p < 0.05$), $\Delta p_{tc}CO_2$ (difference from baseline to maximum $p_{tc}CO_2$) decreased from 11.1 ± 4.2 mmHg to 5.8 ± 3.8 mmHg ($p < 0.05$), and mean $p_{tc}CO_2$ fell from 47.5 ± 6.2 mmHg to 43.8 ± 4.6 mmHg ($p < 0.05$). Objective sleep measures remained stable in the first night of treatment compared with initial PSG (sleep efficiency: 83.2 ± 10.4% vs. 80.0 ± 8.4%, $p = 0.06$; wake after sleep onset [WASO]: 54.1 ± 41.6 min vs. 60.6 ± 42.4 min, $p = 0.1$; N3 percentage: 28.8 ± 12.5% vs. 35.1 ± 9.9%, $p = 0.57$; percentage of REM sleep: 21.3 ± 5.8% vs. 23.9 ± 8.9%, $p = 0.79$).

Discussion

The results of this retrospective analysis show that SDB may be a frequent finding in adult patients with FSHD complaining of sleep-related symptoms, and that NH is associated with disease severity. We also showed that transcutaneous capnometry is superior to pulse oximetry for detecting NH.

This is the third study reporting comprehensive sleep study data for non-ventilated adult patients with FSHD. Compared with previous studies by Della Marca et al. [16] and Moreira et al. [15], an important new feature of our study is that continuous nocturnal CO_2 monitoring was applied using TC. In NMD other than FSHD, TC has been shown to be superior to pulse oximetry in detecting NH [17–19], consistent with our findings. The previous studies showed that a subset of patients with transient hypercapnia during sleep (and during REM sleep in particular) may not be identified when only SpO_2 is recorded. The sensitivity of pulse oximetry to detect NH in patients with various NMD [18] (and amyotrophic lateral sclerosis in particular [17]) has been reported to be below 0.7. Our findings support this, given that the majority of patients with definite hypoventilation on capnometry would not have been identified by pulse oximetry alone. One potential explanation for this is the shape of the oxygen/hemoglobin dissociation curve: in patients with preserved parenchymal gas exchange, arterial oxygen pressure (p_aO_2) moves within the plateau of the curve, and changes do not cause significant alterations in SpO_2.

The results of our study contradict those of a previous analysis reporting a very low prevalence of SDB in FSHD using a population-based observational approach which only focused on patients requiring home ventilatory support [14]. In our cohort, 18/31 patients (58.1%) had SDB, 17 of whom had OSA, seven had NH and OSA, and one had NH. These numbers are higher than those reported previously [15, 16], particularly the proportion of patients in whom NIV was indicated (19.4%). Maximum $p_{tc}CO_2$ was significantly correlated with disease severity as reflected by the CSS, consistent with the results of a study by Moreira et al. who described respiratory muscle weakness and SDB, especially in FSHD

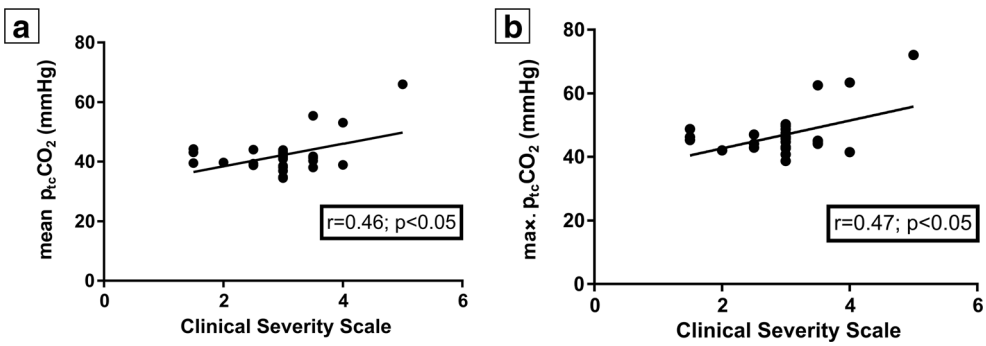

Fig. 2 Correlation between the Clinical Severity Scale score and mean (**a**) and maximum (**b**) transcutaneous carbon dioxide tension ($p_{tc}CO_2$)

Table 2 Subgroup analysis of FSHD patients with and without sleep-disordered breathing

	FSHD patients		*p* value
	With SDB ($n = 18$)	Without SDB ($n = 13$)	
Clinical characteristics			
Age (years)	57.5 ± 16.1	48.5 ± 16.7	NS
BMI (kg/m^2)	25.6 ± 4.5	23.2 ± 3.9	NS
CSS score	3.2 ± 0.7	2.8 ± 0.7	NS
ESS sum score	7 ± 5	7.3 ± 4.3	NS
PSQI global score	8.9 ± 4.6	6.6 ± 3.4	NS
FSS score	4.4 ± 1.3	4.2 ± 1.4	NS
Sleep parameters[a]			NS
TST (min)	353.9 ± 75.4	360.5 ± 57.4	NS
Sleep efficiency (%)	76.6 ± 13.4	82.1 ± 12.9	NS
WASO (min)	74.5 ± 44.4	61.1 ± 45.3	NS
N3 sleep (% TST)	27.7 ± 9.2	27.8 ± 10.6	NS
REM sleep (% TST)	17.8 ± 7.2	22.6 ± 10.4	NS
Sleep Stage Changes Index (/h TST)	14.3 ± 5.7	10.8 ± 4.2	NS
Arousal index (/h)	17.9 ± 6.9	10.1 ± 5.4	*< 0.05*
Respiratory arousal index (/h)	6.2 ± 4.2	0.3 ± 0.3	*< 0.05*
Respiratory results			
AHI (/h)	14.6 ± 9.9	1.1 ± 0.9	*< 0.05*
ODI (/h)	13 ± 14.2	1 ± 1	*< 0.05*
cAI (/h)	1.9 ± 2.6	0.2 ± 0.2	*< 0.05*
oAI (/h)	5.8 ± 6.2	0.1 ± 0.2	*< 0.05*
Minimum SpO_2 (%)	82.2 ± 9.4	90.2 ± 3.4	*< 0.05*
Mean SpO_2 (%)	93.8 ± 3.7	96.6 ± 1	*< 0.05*
Time with $SpO_2 < 90\%$ (min)	33.5 ± 104.6	1.1 ± 1.9	n.s.
Mean $p_{tc}CO_2$ (mmHg)	44.2 ± 7.1	39.6 ± 2.8	*< 0.05*
Maximum $p_{tc}CO_2$ (mmHg)	49.3 ± 8.1	44.1 ± 2.8	*< 0.05*
$\Delta ptcCO_2$ (mmHg)	7.3 ± 4.1	5.5 ± 2.4	NS
Early morning blood gas analysis			
pO_2 (mmHg)	85 ± 19.8	93.8 ± 19.2	NS
pCO_2 (mmHg)	40.4 ± 4.3	36.8 ± 2.9	*< 0.05*
HCO_3^- (mmol/L)	27 ± 3	27 ± 6	NS

p values below 0.05 are shown in italic format

Values are depicted as mean and standard deviation

AHI, apnea-hypopnea index; *BMI*, body mass index; *cAI*, central apnea index; *CSS*, Clinical Severity Scale; *ESS*, Epworth Sleepiness Scale; *FSS*, Fatigue Severity Scale; *HCO_3^-*; standard bicarbonate; *N3*, slow wave; *NS*, not statistically significant; *oAI*, obstructive apnea index; *ODI*, oxygen desaturation index; *PSQI*, Pittsburgh Sleep Quality Index; *pCO_2*, partial pressure of carbon dioxide; *pO_2*, partial pressure of oxygen; *$p_{tc}CO_2$*, transcutaneous carbon dioxide tension; *$\Delta p_{tc}CO_2$*, difference between baseline and maximum *$p_{tc}CO_2$*; *REM*, rapid eye movement; *SDB*, sleep-disordered breathing; *SpO_2*, peripheral oxygen saturation; *TST*, total sleep time; *WASO*, wake after sleep onset

[a] Polysomnography was performed in 28 patients

patients with early symptom onset or severe disease manifestation [15]. In our study, SDB was present in all patients who had a CSS score of 4.0 or higher (reflecting significant proximal leg weakness).

The relatively high prevalence of SDB in our study most likely reflects the fact that admission to the sleep laboratory was driven by the presence of clinical symptoms such as non-restorative sleep, sleep disturbances, and impaired daytime performance. EDS was only reported by a small number of patients but significant fatigue was highly prevalent. Fatigue is likely to be multifactorial, but may be a clinical symptom suggestive of SDB and should always be taken into account when sleep study

results are interpreted and ventilatory support is considered in FSHD patients. Guidelines on the indications for NIV in patients with NMD suggest that both clinical symptoms and the presence of either significant respiratory muscle weakness or nocturnal hypercapnia are required [30].

In our cohort of FSHD patients, neurological handicap was more severe in subjects with versus without NH. This did not translate into worse objective markers of sleep quality on diagnostic sleep studies which can be found in patients with more progressive NMD (e.g., amyotrophic lateral sclerosis) and NH [31]. This may indicate that evolvement of respiratory muscle weakness and NH is slow in non-fatal muscular dystrophies, and substantial sleep disruption by evolving hypercapnia may not occur for a long time.

Rapid improvement of nocturnal respiration and gas exchange by NIV in the first night of bi-level treatment has been shown in various other NMD [31–33].

The present study has some limitations which need to be acknowledged. Firstly, in order to evaluate the predictive value of measures reflecting respiratory muscle strength for SDB in our cohort, it would have been desirable to collect data on forced vital capacity and inspiratory/expiratory mouth pressures. However, due to the retrospective design of our study, these measurements were only available in a small subset of patients. Secondly, selection bias was likely given that patients had sleep-related symptoms, and the prevalence estimates may not be applicable to an unselected population of patients with FSHD.

In conclusion, this study adds to the body of evidence showing that SDB is present in a substantial number of patients with FSHD complaining of sleep-related symptoms, and that sleep studies that do not assess hypercapnia might underestimate the prevalence of hypoventilation in FSHD. We showed that transcutaneous capnometry is superior to pulse oximetry alone and is therefore appropriate for baseline evaluation of sleep-related breathing in patients with FSHD.

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Compliance with ethical standards

This retrospective study was conducted in accordance with the regulations set by the local ethics committee (Ethikkommission der Ärztekammer Westfalen-Lippe und der Medizinischen Fakultät der Westfälischen Wilhelms-Universität Münster).

Conflict of interest JS is supported by the Else-Kröner-Fresenius Stiftung (Grant A109) and by Kommission für Innovative Medizinische Forschung an der Medizinischen Fakultät Muenster (IMF Grant SP 11 18 15) outside this work. PY and MB have received speaker honoraria and financial research support from Löwenstein Mecdical GmbH (Bad Ems, Germany) or the Löwenstein Foundation (Bad Ems, Germany), respectively. MD received fees for speaking and advising from ResMed, Philips, and Linde. MD received unrestricted research grants from ResMed. All other authors declare that they have no conflicts of interest.

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