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Detecting sleep apnea in adults with Down syndrome using WatchPAT: A feasibility study

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ABSTRACT

Background: In daily practice, sleep apnea is underdiagnosed in people with Down syndrome. The WatchPAT can detect sleep apnea in a less invasive way.
Aim: This study aimed to evaluate the feasibility of the WatchPAT to detect sleep apnea in individuals with Down syndrome.
Methods and procedures: Thirty-one participants with Down syndrome (aged 18+) were included. Sleep apnea was detected with the WatchPAT and compared to results of the STOP-Bang Questionnaire (current practice). Experiences of participants, caregivers and clinicians were studied using a combination of quantitative and qualitative methods.
Outcomes and results: Among the 68% of participants who accepted the WatchPAT, sleep apnea was detected in 95% of participants. Younger participants and participants with mild/moderate intellectual disabilities were more likely to accept the device. STOP-Bang did not detect most cases of sleep apnea. For the degree of sleep apnea, interrater reliability was substantial ($k = 0.71$) to almost perfect ($k = 0.91$). Considering experiences, caregivers and clinicians were predominantly positive about the WatchPAT.
Conclusions: Our study showed that the WatchPAT is a promising device to detect sleep apnea in people with Down syndrome. Compared to polysomnography, detection with this device is less invasive and less burdensome for people with Down syndrome. Furthermore, the WatchPAT is a relatively accessible solution to implement in care institutions.

1. Introduction

Sleep apnea, a serious sleep disorder that can occur in all age groups (Lettieri et al., 2005) is caused by frequent disturbances in

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breathing during sleep due to closure of the airways (obstructive) or failure of the brain to regulate breathing (central) (Mayo Clinic, 2021). Sleep apnea is associated with increased morbidity including daytime sleepiness, hypertension, cardiovascular diseases, type 2 diabetes (Mayo Clinic, 2021; Shahar et al., 2001), decreased quality of life (Chen et al., 2013; Rundo, 2019; Turkington et al., 2001), and increased mortality (Marshall et al., 2008; Young et al., 2008).

Sleep problems are commonly reported in people with Down syndrome (Lal et al., 2015). According to a polysomnography study, 78% of people with Down syndrome have sleep apnea that was not detected by self-reported sleep measures or reported by caregivers (Giménez et al., 2018). In comparison, prevalence varies between 2% and 26% in the general population without intellectual disabilities (Benjafield et al., 2020; Young et al., 1993). This significant higher prevalence in people with Down syndrome is due to various anatomical and physiological characteristics (Giménez et al., 2018; Lal et al., 2015). In addition, sleep apnea is usually more severe in people with Down syndrome as compared to the general population (Trois et al., 2009).

Polysomnography is the accepted gold standard for detecting sleep apnea, but is time-consuming, costly and invasive (Yalamanchali et al., 2013). Consequently, screening and detecting sleep apnea in people with Down syndrome are difficult. In daily practice, detection of sleep apnea is usually based on a clinical (hetero)anamnesis by a physician aided by questionnaires such as Berlin, Epworth and STOP-Bang (Chiu et al., 2017; de Carvalho et al., 2020). However, these questionnaires do not reflect the sleep disturbances detected by polysomnography (Chiu et al., 2017; Giménez et al., 2018). Consequently, sleep apnea is underdiagnosed in daily practice, resulting in a lack of (adequate) treatment in individuals with Down syndrome.

Early detection and treatment of sleep apnea is important, because people with Down syndrome are more susceptible to cardiovascular and neurocognitive consequences of sleep apnea, such as short- and long-term memory problems and language impairments (Simpson et al., 2018). In addition, undiagnosed apnea can cause symptoms that could be erroneously attributed to other diseases, such as dementia (Moriconi et al., 2015). Moreover, sleep disorders may lead to behavioral problems (Dekker et al., 2015; Gimenez et al., 2021). Consequently, caregiving/support or treatment may be inappropriate leading to a reduced quality of life. Treating sleeping disorders may improve cognition and quality of life and may promote healthy aging in adults with Down syndrome (Giménez et al., 2018).

Polysomnography is invasive and burdensome, especially for people with intellectual disabilities. Considering the relevance of a sleep apnea diagnosis, it is important to detect sleep apnea in a less invasive way for this vulnerable population (Krishnaswamy et al., 2015). To that end, portable recording devices have been developed for home sleep testing, such as the WatchPAT (Itamar Medical Ltd, 2020).

The WatchPAT is a home sleeping testing system based on a wrist-worn watch, a finger probe and a snoring sensor. It detects apnea indirectly by measuring sympathetic arousal in response to an upper airway obstruction. The finger probe records peripheral arterial tonometry (PAT), heart rate and oxygen saturation levels (pulse oximeter) together with actigraphy data from a 3D accelerometer that is embedded in the watch and a snoring, body position and chest movement sensor that has to be positioned under the sternal notch. Respiratory events are identified using a combination of PAT signal attenuation, heart rate changes, and desaturation. The sympathetic arousal is measured by the WatchPAT and processed by an automated software algorithm that produces a full sleep report. The report is then reviewed and manual editing is applied if necessary (Itamar Medical Ltd, 2020).

The WatchPAT has been studied in various patient groups in the general population of different ages and sexes, including chronic diseases (Jen et al., 2020; Pang et al., 2007; Pillar et al., 2020; Weimin et al., 2013; Yalamanchali et al., 2013; Yuceege et al., 2013). Applicability and validity have been investigated and compared to polysomnography with promising results as shown in a meta-analysis by Yalamanchali et al. (2013). Surprisingly, despite the high prevalence of sleep apnea in people with Down syndrome and current underdiagnoses in daily practice, the WatchPAT has not been studied in this population so far.

Therefore, this study aims to assess the feasibility of using the WatchPAT for detecting sleep apnea in people with Down syndrome.

2. Methods

2.1. Study design

Feasibility was studied using a combination of quantitative and qualitative research methods. Using a quantitative design, we compared the WatchPAT to the current clinical practice of detecting sleep apnea in adults with Down syndrome. Since polysomnography is often too burdensome for people with Down syndrome, physicians have to rely on hetero anamnesis information from family members or caregivers. The STOP-Bang questionnaire is a commonly used tool for this. Promoting and hampering factors regarding accepting and using the WatchPAT experienced by people with Down syndrome, caregivers and clinicians were studied by using (Likert-type) questionnaires and semi-structured qualitative interviews. We used the Consolidated Criteria for Reporting Qualitative Research (COREQ) (Tong et al., 2018).

2.2. Participants

Three types of study groups were distinguished. Firstly, people wearing the WatchPAT were eligible to participate if they had phenotypical diagnosis of Down syndrome and were 18 years and older. A permanent pacemaker was considered an exclusion criterion as this may invalidate the WatchPAT measurements (Itamar Medical Ltd, 2020).

Participants were recruited via Alliade, a large care institution in the Dutch province of Friesland, which is representative for many intellectual disability care institutions in The Netherlands. A purposive sampling strategy ensured variation in intellectual disability levels, age and sex. In total, 51 participants were invited to participate in the study, of which 31 gave informed consent (61%). Reasons

for not consenting were for example that legal representatives found detecting sleep apnea unnecessary because participant sleeps well according to them, or because they expect that participant will not cooperate with treatment, or because participant is susceptible for sensory overload.

Secondly, caregivers who were present in the evening before or morning after the participant slept with the WatchPAT were asked to complete a questionnaire (n = 29) about their experiences with the WatchPAT. Ten of them were also sampled purposively for qualitative interviews.

Thirdly, four clinicians (three intellectual disability physicians and one nurse practitioner) involved in interpreting the WatchPAT reports and underlying measurements were interviewed. In this study, we used a practice-oriented approach and therefore included a nurse practitioner in order to test the applicability of the WatchPAT in daily practice of an intellectual disability care institution.

2.3. Ethics and consent

The Medical Ethical Review Board of the University Medical Center Groningen (UMCG) decided that the Dutch Medical Research Human Subjects Act did not apply to this study (METc 2020/354). The study was registered in the UMCG Research Register (no. 202000484) and conducted in accordance with the EU General Data Protection Regulation and Declaration of Helsinki. Legal representatives of potential participants with Down syndrome were informed by intellectual disability psychologists and subsequently received an information folder. Written informed consent for participating in this study was obtained from legal representatives (proxy consent) with assent from people with Down syndrome. If participants clearly resisted wearing the WatchPAT, e.g., by removing the device, study participation was terminated.

2.4. Data collection

2.4.1. General participants' characteristics

The following socio-demographic and clinical characteristics were obtained from (medical) records: age, sex, living situation, and dementia (yes/no). Data were collected using the Research Electronic Data Capture (REDCap) system (Harris et al., 2009, 2020) hosted at Alliade.

2.4.2. Assessment of intellectual disability

Since we hypothesize that intellectual disability level (i.e., understanding) might influence the acceptance of the WatchPAT, an intelligence assessment was performed. To determine the level of intellectual disability, the WPPSI-III-NL (Hurks et al., 2010), SON-R 2–8 (Tellegen & Laros, 2017) or Bayley-III-NL (Bayley, 2006) were used. Based on information in (medical) records and clinical judgement of clinicians and intellectual disability psychologists, one of these three assessments was selected depending on the expected level of intellectual disability. Assessments were not conducted if the level of intellectual disability was already assessed within five years prior to this study, legal representatives did not consent to performing the assessment, participants refused to comply during the assessment or participants had (suspected) dementia. For those participants, the level of intellectual disability level was based on clinical judgment and (medical) records.

2.4.3. Current practice: STOP-Bang

In current practice, the STOP-Bang Sleep Apnea Questionnaire is often used to screen for sleep apnea (Chung et al., 2008, 2012). Its scoring model consists of eight yes/no-questions (score: 1/0). An intellectual disability physician, who did not have an actual treatment relationship with the participant and was not involved in interpreting the participant's WatchPAT measurement, completed the STOP-Bang questionnaire in a Microsoft Teams meeting (due to COVID-19 pandemic) with the participant's caregiver (i.e., parent or caregiver). Clinical measures necessary for completing the STOP-Bang, such as length, weight, blood pressure and neck circumference were measured when the WatchPAT was delivered. Based on the STOP-Bang questionnaire, the physician established whether participants had a low, intermediate or high risk of sleep apnea.

2.4.4. WatchPAT measurements

Participants and caregivers received written and oral instruction about the use of the WatchPAT. Participants had the option to sleep with a dummy device for a maximum of two nights to get used to the WatchPAT. If participants clearly resisted wearing the WatchPAT, for example by removing (dummy) devices, study participation was terminated.

Participants had to wear the WatchPAT for at least 4 h to get enough reliable data. WatchPAT data were anonymously uploaded in CloudPAT software (Itamar Medical), a web-based (cloud) management system for sleep studies hosted on European servers. Data were sent to clinicians for interpretation. All data were scored based on the 3% guideline. That is, clinicians had to review the measurements in one of the following situations: difference between ODI and pAHI > 10 points; both ODI and pAHI < 30 points; suspicion of arrhythmia or many central apneas. One physician and the nurse practitioner interpreted all WatchPAT measurements. Two other physicians who were also involved in interpreting the STOP-Bang data only interpreted WatchPAT data from participants for whom they did not interpret the STOP-Bang data. In the end, each WatchPAT measurement was interpreted by two physicians and one nurse practitioner. The following data from the clinicians' final reports were used: degree of sleep apnea based on pAHI (no, mild, moderate, severe) and type of sleep apnea. All clinicians received training in and followed the WatchPAT manual for interpreting WatchPAT data (Itamar Medical Ltd, 2020).

2.4.5. Experiences from participants, caregivers and clinicians

Participants: A 7-item questionnaire was developed based on the Intrinsic Motivation Inventory (McAuley et al., 1989; Ryan & Deci, 2000) which is derived from the Basis Psychological Need Satisfaction and Frustration Scale (BPNSFS) (Chen et al., 2015). Items were scored on a 5-point Likert scale ranging from negative to positive using smileys.

Caregivers: The Measurement Instrument for Determinants of Innovations (MIDI) was used to assess caregivers' experiences of working with the WatchPAT (Fleuren et al., 2014a, 2014b). The following determinants were assessed: procedural clarity, completeness, complexity, relevance for client, benefits, drawbacks, outcome expectations, task orientation, client cooperation, social support, knowledge, self-efficacy, and time available. Items were scored on a 5-point Likert scale ranging from negative to positive, which were recoded into a 3-point scale (agree, neutral and disagree) for a comprehensive presentation of item responses in the results section.

A number of caregivers was interviewed using semi-structured interviews with a topic-based interview guide consisting of open-ended questions to obtain more in-depth insights in caregivers' experiences with the WatchPAT and circumstances and factors that promoted or hampered its use. Interviews (duration 20–33 min) were conducted by two researchers (MA and ZdJ). Researchers and caregivers were not acquainted before the study. Interviews took place between March and June 2021 via Teams (n = 9) or telephone (n = 1). Data collection stopped after reaching saturation (i.e., when no new concepts emerged during additional interviews).

Clinicians: Involved clinicians (n = 4) were interviewed about their experiences with interpreting WatchPAT data. Semi-structured interviews with a topic-based interview guide were conducted by one researcher (MA). Interviews (duration 16–34 min) took place in June 2021 via Teams.

2.5. Data analysis

2.5.1. Quantitative analyses

Descriptive statistics were used to describe the study group characteristics and the WatchPAT conclusion (no, mild, moderate, severe sleep apnea). Independent t-tests and Fisher's exact tests were used to compare individuals accepting the WatchPAT vs. those who did not. Percent agreement and Cohen's kappa coefficient were computed to assess interrater reliability for the degree of sleep apnea (no, mild, moderate, severe). A coefficient $k < 0$ reflects poor agreement, 0–0.0.20 slight, 0.21–0.4 fair, 0.41–0.60 moderate, 0.61–0.80 substantial and above 0.81 almost perfect agreement (Landis & Koch, 1977). Questionnaire data were analysed using descriptive statistics. Quantitative analyses were performed using SPSS statistical software (version 26.0).

2.5.2. Qualitative analyses

Interviews were transcribed verbatim and subsequently analysed using thematic analysis (Braun & Clarke, 2006) consisting of five steps. In the first step, two researchers (MA and ZdJ) independently read full transcripts (familiarizing with the data). In the second step, transcripts were openly coded (generating initial codes). In step 3 (searching for themes) data were interpreted, categorised and divided into themes. This was an iterative process of reading, categorising, rereading and refining. In step 4, the researchers (MA and ZdJ) discussed and refined the division of themes until they had reached consensus (reviewing themes). In the final step, defining and

Table 1
Participants' characteristics.

Characteristics	Total participants N = 31 (100%)	Accepted N = 21 (68%)	Not accepted N = 10 (32%)	P-value
Age (yr)				.01
Mean ± SD	46.6 ± 12.2	43.3 ± 13.0	53.7 ± 6.1	
Range	24–62	24–61	43–62	
Sex (male)	18 (58%)	12 (57%)	6 (60%)	.99
Level of intellectual disability*				
Mild	1 (3%)			
Mild/moderate	5 (16%)			
Moderate	10 (32%)			
Moderate/severe	1 (3%)			
Severe/profound	14 (45%)			
Level of intellectual disability**				.01
Mild/moderate	17 (55%)	15 (71%)	2 (20%)	
Severe/profound	14 (45%)	6 (29%)	8 (80%)	
Living situation				
At home	2 (7%)			
Care institution	28 (93%)			
(Suspected) dementia				.58
Yes	4 (13%)	2 (10%)	2 (20%)	
No	27 (87%)	19 (90%)	8 (80%)	

* For 27 participants, intelligence assessments were performed (WPPSI-III-NL (n = 22); SON-R 2–8 (n = 2); Bailey-III-NL (n = 3)). Assessments were not possible for three participants (i.e. no consent (n = 2), non-compliance (n = 1).

** Based on clinical judgement two study groups were distinguished: 1) Mild/moderate intellectual disability, 2) Severe/profound intellectual disability.

naming themes, phrasing of themes was tailored to the research question. To enhance trustworthiness, results are illustrated with authentic citations (Elo & Kyngäs, 2008). Qualitative data analysis was performed using ATLAS.ti (version 9).

3. Results

3.1. Participants' characteristics

In total, we included 31 participants. Table 1 presents participants' characteristics.

3.2. Acceptance of the WatchPAT

Among the 31 participants, 21 (68%) accepted the WatchPAT, i.e., slept at least 4 h with the device. Due to non-successful measurements, nineteen WatchPAT measurements were finally included in analyses. Fig. 1 presents a flow chart including reasons for not accepting the WatchPAT. Table 1 presents characteristics comparing participants who accepted the WatchPAT with participants who did not accept it. Evidently, younger participants (vs. aged) and those with mild/moderate intellectual disabilities (vs. severe/profound) were more likely to accept the WatchPAT.

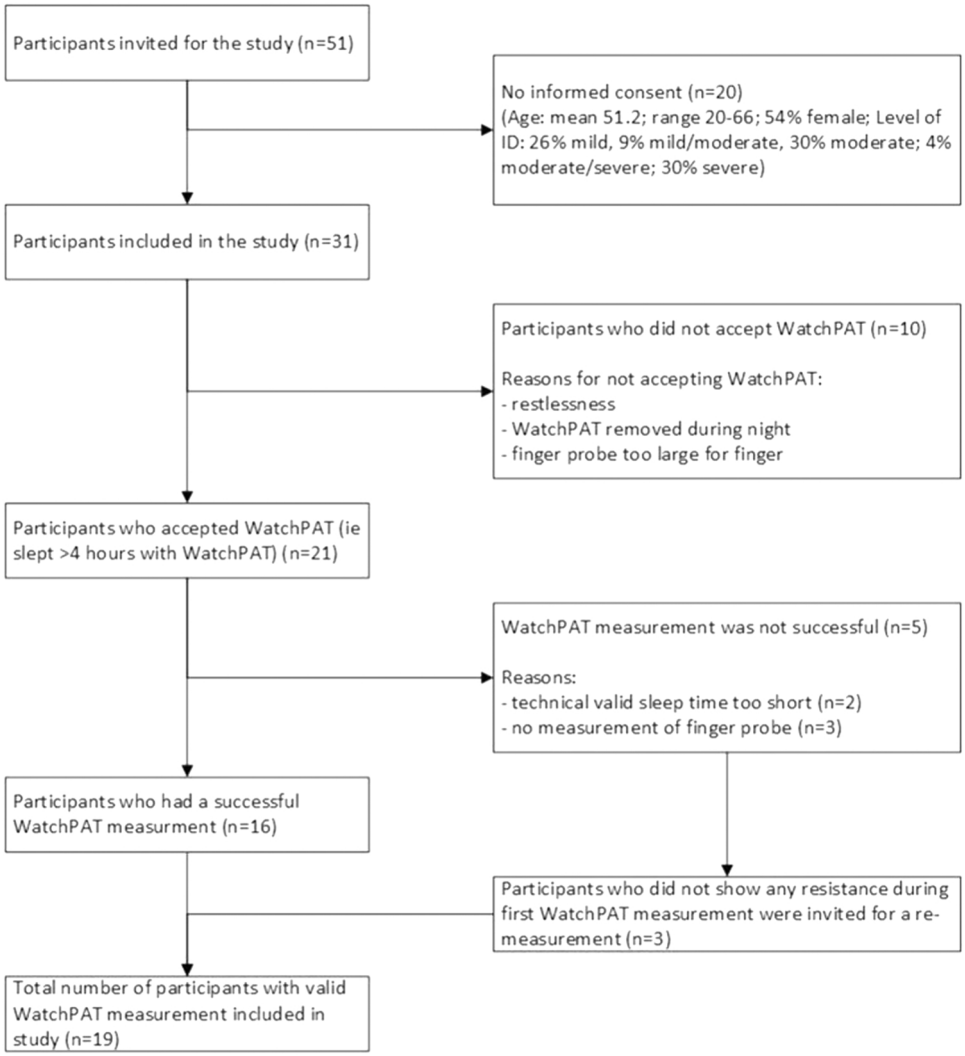

Fig. 1. Flowchart of inclusion of the participants.

Table 2
Comparison of WatchPAT conclusions with STOP-Bang questionnaire.

	STOP-Bang		
	Low risk (N = 12)	Intermediate risk (N = 5)	High risk (N = 2)
WatchPAT			
No sleep apnea (N = 1)	1 (5%)	–	–
Mild sleep apnea (N = 7)	4 (21%)	3 (16%)	–
Moderate sleep apnea (N = 5)	3 (16%)	2 (11%)	–
Severe sleep apnea (N = 6)	4 (21%)	–	2 (11%)

3.3. Detecting sleep apnea with the WatchPAT

3.3.1. Results of the WatchPAT

In total, nineteen participants had a successful WatchPAT measurement. Of those, one participant had no sleep apnea (5%), seven participants had mild sleep apnea (37%), five moderate sleep apnea (26%) and six severe sleep apnea (32%). All participants had obstructive sleep apnea, of whom two had a combination with central sleep apnea. Six participants had a postural sleep apnea, of whom one was REM-sleep dependent.

3.3.2. Current practice

Table 2 shows the comparison of WatchPAT and STOP-Bang outcomes. Evidently, 58% of the participants had a low risk for sleep apnea according to the STOP-Bang, but had a mild, moderate or severe sleep apnea according to the WatchPAT. Those who scored a high risk for sleep apnea on the STOP-Bang indeed had severe sleep apnea according to the WatchPAT.

3.3.3. Interrater reliability

Interrater reliability for the degree of sleep apnea (no, mild, moderate, severe) was found to be substantial to almost perfect: Cohen's kappa between physician 1 and 2 was k = 0.91 (percent agreement: 94%), between physician 1 and the nurse practitioner k = 0.71 (79%) and between physician 2 and the nurse practitioner k = 0.91 (94%).

3.4. Experiences from participants, caregivers and clinicians

3.4.1. Participants

Among the 31 participants, 24 completed the questionnaire regarding their experiences with the WatchPAT. As Table 3 demonstrates, experiences varied: whereas the majority is positive about the device, a substantial part experienced the WatchPAT as more negative.

3.4.2. Caregivers

In total, 29 caregivers filled in the questionnaire. Ten of them were also interviewed. Table 4 presents their characteristics.

Table 5 presents the results of the MIDI questionnaire. Most caregivers perceived the information regarding procedure clear (97%) and complete (93%), perceived the WatchPAT as not too complex to use (97%), had enough knowledge to use the WatchPAT (86%), and could count on adequate assistance from colleagues if necessary (83%). Caregivers agreed to a lesser extent about whether the device is suitable for all people with Down syndrome and whether they expect them to wear the WatchPAT (Table 5).

Four themes emerged from the thematic analysis of interviews: relevance, working experience, impact on participants, and future implementation. Fig. 2 presents the themes and categories, which are described in more detail below and illustrated with interview quotes.

Table 3
Participants' experiences of the WatchPAT.

Item	Positive	Neutral	Negative
I found the WatchPAT interesting.	9 (38%)	4 (17%)	11 (46%)
I can take off the WatchPAT whenever I want to.	9 (43%)	6 (29)	6 (29%)
I wanted to wear the WatchPAT while sleeping.	11 (48%)	1 (3%)	11 (48%)
I received an explanation about the WatchPAT in advance	19 (79%)	2 (8%)	3 (13%)
I know why I wear the WatchPAT	12 (52%)	5 (22%)	6 (26%)
The explanation of the caregiver was clear.	14 (58%)	5 (21%)	5 (21%)
I felt comfortable when the caregiver put the WatchPAT on.	15 (65%)	1 (4%)	7 (30%)

Table 4
Caregivers' characteristics.

Characteristics	Total participants N = 29
Age (yr)	
Mean ± SD	42.0 ± 15.4
Range	20–74
Sex (male)	3 (10%)
Caregiver relation	
Professional caregiver	25 (86%)
Parent	4 (14%)
How long have you known the participant	
Less than 2 years	9 (31%)
2–5 years	7 (24%)
5–10 years	6 (21%)
10–20 years	1 (3%)
More than 20 years	6 (21%)

Table 5
Caregivers' experiences assessed with the MIDI.

Item	Agree	Neutral	Disagree
The WatchPAT clearly describes the activities I should perform and in which order.	28 (97)	0 (0)	1 (3)
The WatchPAT provides all the information and materials needed to work with it properly.	27 (93)	0 (0)	2 (7)
The WatchPAT is too complex for me to use.	1 (3)	0 (0)	28 (97)
I think the WatchPAT is relevant for my clients.	11 (38)	9 (32)	8 (29)
Using the WatchPAT have benefits.	16 (54)	10 (35)	3 (10)
Using the WatchPAT have drawbacks.	12 (41)	6 (21)	11 (38)
I expect that clients I work with will generally cooperate when I use the WatchPAT.	22 (76)	5 (17)	2 (7)
I think it is part of my job to use the WatchPAT.	17 (60)	7 (24)	5 (17)
Clients will generally cooperate if I use the WatchPAT.	7 (24)	14 (48)	8 (28)
I can count on adequate assistance from my colleagues if I need it to use the WatchPAT.	24 (83)	0 (0)	5 (17)
I know enough to use the WatchPAT.	25 (86)	2 (7)	2 (7)
Should you wish to do so, do you think you can put the WatchPAT into practice?	2 (7)	14 (48)	15 (45)
The organisation provides me with enough time to include the WatchPAT as intended in my day-to-day work.	16 (56)	9 (31)	4 (13)

3.4.2.1. Theme: Relevance. Almost all caregivers found it important to detect sleep apnea to enable treatment that may improve participants' quality of life. Compared to polysomnography, caregivers see benefits of using the WatchPAT: measurements can take place in a safe and familiar environment, which is less burdensome for participants. Moreover, caregivers indicated that detecting sleep apnea is important for them as it may explain to them why someone is tired during the day or falls asleep.

> *Well, it can be done at home, in a safe environment, so to speak. (…) I think that is a big advantage. And [participants] sleep in their own beds, in their own surroundings. Those are always beneficial aspects, in my opinion. (Int 7)*

3.4.2.2. Theme: Working experience. In line with the MIDI-results, caregivers found instructions clear and working with the device easy. For proper measurements, the probe needed to be placed correctly over the finger by removing the adhesive strip to create a vacuum, which was experienced as somewhat difficult by some caregivers. Some caregivers indicated that they had time available in their schedule, while others indicated that they had no time. As soon as caregivers get stress due to a lack of time, this led to feelings of resistance among participants.

> *[The device] is very small, it is a watch and you have to press start button, that is all you have to do. Hoping that the participants keeps it in place. I found that very pleasant. (C1)*

> *You have to bear it in mind and that is all, put it down in my agenda, no further troubles, no. (C8)*

3.4.2.3. Theme: Impact on participants. Caregivers used various ways to inform and motivate participants, for instance by letting them decide the specific moment/night to sleep with the WatchPAT or by "selling" the WatchPAT by stating that it is important, a very nice watch or something unique. Furthermore, they stressed that it is important to take time to inform participants.

> *I do not know it had succeeded if I had told 'tomorrow we are going to do this'. Now I thought 'it has to happen within a week', so I asked [the participant] 'when do you want to wear it?'. So, the participant is in charge, more or less. (C1)*

> *By praising [the device] to the skies, making it special, just for you, making it unique. (C5)*

According to caregivers, various participants found the WatchPAT interesting or "cool". Some participants were proud that they had succeeded. In contrast, others found the WatchPAT thrilling or scary, became restless, or associated the WatchPAT with being sick.

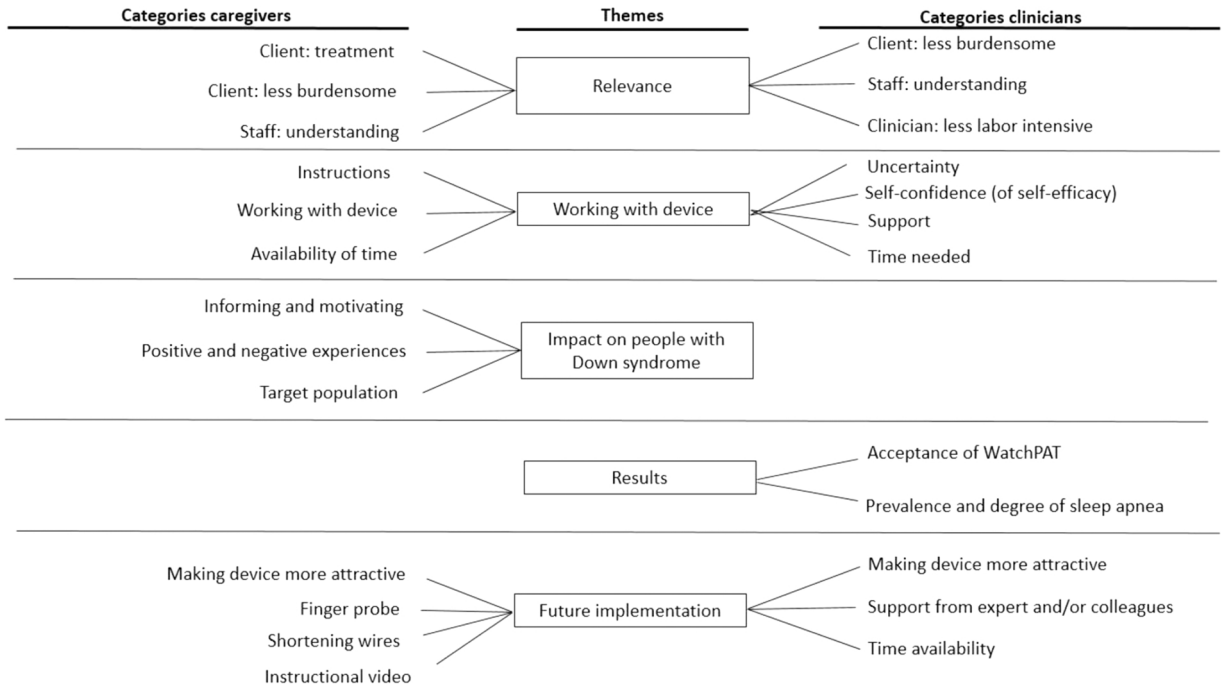

Fig. 2. Thematic analyses of semi-structured interviews with caregivers and clinicians.

Many participants who did not accept the WacthPAT found the finger probe annoying. Sensory overload was also mentioned as reason for not accepting it.

> *And she was playing with the threads. She threw some parts on the floor and she was playing with the other parts. She just used it as a toy… She is very physical, she is functioning at the level of 1,5 to 2 years and it does not fit her picture, it should not be there. (C4)*

Caregivers had different ideas about for whom the WatchPAT would be suitable. Several caregivers indicated that individuals with mild intellectual disabilities are more likely to accept the WatchPAT, while others expected those with severe/profound intellectual disabilities to accept it better. Furthermore, caregivers expected that accepting the WatchPAT will become more difficult with aging, participants with dementia, participants who need structure and participants who move a lot during their sleep. Several caregivers indicated that they would always like to try it with every individual.

> *I could think that it is not going to work, but if we do not try, how will we ever know? (C4)*

3.4.2.4. Theme: Future implementation. Caregivers' suggestions are mainly related to improving the WatchPAT device itself, for example making the watch more attractive, smaller and less heavy. As the finger probe was tedious for several participants, caregivers suggested to design a smaller probe or use more flexible material for the probe to enable bending of the finger. Moreover, shorter wires from watch to chest sensor were recommended, among others to reduce a potential risk of choking.

3.4.3. Clinicians

The four clinicians involved in interpreting the WatchPAT report and reviewing measurements were interviewed. Thematic analysis of transcripts revealed four main themes: relevance, working experience, outcome and future implementation. Fig. 2 presents the themes which are described below and illustrated with quotes.

3.4.3.1. Theme: Relevance. All clinicians found it important to map sleep patterns, because it can explain why someone sleeps poorly or is tired during the day. They all considered the WatchPAT as an easily applicable instrument that is less burdensome for participants (compared to polysomnography) and less labor intensive to interpret (compared to actigraphy) for themselves. In addition, clinicians can interpret the WatchPAT data themselves in contrast to polysomnography which requires a more specialized infrastructure that is not available in most intellectual disability care institutions.

> *Of course, it is way less burdensome than a polysomnography with all these threads and having to sleep elsewhere [in a specialized sleep center] for a night. (P3)*

3.4.3.2. Theme: Working experiences. All clinicians were trained in interpreting WatchPAT reports and underlying measurements (raw

data). Although they considered the training useful and interesting, it was also perceived as complicated at first. In particular, the measurements were experienced as overwhelming. This initially led to uncertainty and some clinicians had to pass a threshold to start interpreting the reports. All clinicians indicated that the more reports and measurements they had interpreted, the more confident they became. Confirmation of their conclusion by an expert and consulting the manual for reviewing measurements also resulted in more self-confidence. Time required for interpretation varied substantially in time depending on the complexity of cases and thus whether the measurements had to be checked and possible adapted.

> *Well, I actually liked it. At the start I found it challenging. Specially during the first trainings I thought 'oh, what have I gotten myself into?'. After the measurements you see these quite complicated patterns. But the more I had seen, the easier it got. (P1)*

> *It is just like driving lessons. In the end you have to do it on your own. You have put in the miles to know what you are doing. (P2)*

> *A few [cases] were so clear that I thought 'I won't dive into the raw data here because it's so obvious, one more or less won't make a difference to the final outcome'. I think the doubtful cases were the hardest, those at the edge of moderate or severe [apnea] (…) they also took the most of my time, because I thought 'if I can remove some things [events], it will surely have an effect on the official outcome'. (NP)*

3.4.3.3. Theme: Outcome. Clinicians were surprised that more participants accepted the WatchPAT than they had expected. They had expected more problems with the finger probe. Most clinicians found it remarkable that practically all participants had some degree of sleep apnea. They were also shocked by the severity of sleep apnea in some participants.

> *What (…) strikes most is that a lot of them actually accept it, (…) I definitely had my doubts if they would accept the finger probe. (P1)*

> *It has struck me that al lot of people have quite severe apneas. (…) And that some people have them almost the entire night. One individual had a pAHI of about 90. We really wondered how this person is able to function during the daytime. Yes, fairly shocking, I think. (NP)*

3.4.3.4. Theme: Future implementation. All clinicians recommended to implement the WatchPAT for future use. However, they indicated that a few conditions must be met beforehand, for example, sufficient time must be allocated to interpret the reports, and it would be useful to have an external expert available to consult for questions and support with difficult cases. To become proficient in interpreting reports, it is recommended that a small group of clinicians within a care institution is responsible for this. Finally, one clinician suggested to make the device more attractive for wider applicability. It was suggested to have multiple designs so an individual with Down syndrome can choose the one he/she likes most.

> *I think you have to leave it to a small group [of clinicians] (…) If everyone masters it, then you only do few in a year. Regarding the investment of time that is great. But this way you won't really develop the skill, I think. (P1)*

4. Discussion

The present study evaluated the feasibility of using the WatchPAT to detect sleep apnea in people with Down syndrome. We found that 68% of the participants accepted the WatchPAT. Among them, 95% had some degree of sleep apnea. Younger participants and participants with mild/moderate intellectual disabilities were more likely to accept the device. Compared to the WatchPAT, STOP-Bang showed underreporting of sleep apnea. Almost all participants with a low risk according to STOP-Bang (92%) had some form of sleep apnea according to the WatchPAT. Interrater reliability for the degree of sleep apnea was substantial to almost perfect. Caregivers and clinicians were predominantly positive about the WatchPAT. However, caregivers had doubt whether the WatchPAT would be suitable for every individual with Down syndrome. Initially, clinicians experienced uncertainty about interpreting the first measurements, but gained more self-confidence over time.

We found that sleep apnea was prevalent in 95% of the people with Down syndrome. Sleep problems are commonly reported in people with Down syndrome (Lal et al., 2015) and the prevalence reported here is largely in line with previous studies like Gimenez et al. (2018)(78%) and Trois et al. (2009)(94%). The somewhat lower percentage found by Gimenez et al. (2018) might be explained by the fact that participants in that were younger and only had mild/moderate intellectual disabilities.

About two thirds of people with Down syndrome accepted the WatchPAT in this study, which is higher than clinicians had expected beforehand. Although we found that younger people and people with mild/moderate intellectual disabilities were statistically significant more likely to accept the WatchPAT, several older participants or participants with severe/profound intellectual disabilities accepted the WatchPAT as well. Considering the high prevalence of sleep apnea among people with Down syndrome, it is advisable to screen the entire population using the WatchPAT regardless of age or level of intellectual disability. In this study, a dummy device was available for participants to get used to the device. In daily practice, it turned out that several caregivers expected that the participant could sleep directly with the real WatchPAT. This was successful in all cases. However, it emerged from the interviews that sleeping with the dummy for two nights is insufficient for some other clients to get used to the device. Therefore, it is recommended to let caregivers determine if and for how long a dummy device is needed.

For the degree of sleep apnea, interrater reliability between the two physicians can be considered almost perfect (Landis & Koch, 1977), indicating that personal characteristics of clinicians did not evidently influence the interpretation of the WatchPAT

measurements. Interrater reliability between the physician and the nurse practitioner varied from substantial (0.71) to almost perfect (0.91), indicating that nurse practitioners – like physicians – could interpret the WatchPAT data as well. This makes it more feasible to implement the device in intellectual disability care institutions.

Our study revealed a gap between subjective STOP-Bang scores and objective WatchPAT measurements. We showed that informant-based questionnaires (i.e., STOP-Bang) did not reflect sleep disturbances in this population, resembling previous findings (Giménez et al., 2018; Grantham-Hill et al., 2020; Tadokoro et al., 2020). This is potentially related to the fact that the questionnaire reflects the caregivers' perceptions, but caregivers are generally not present at night in the bedroom (which is different from a partner), making it difficult for them to answer questions regarding, for example, snoring. As validated questionnaires to screen sleep disturbances in people with Down syndrome are lacking, we used the STOP-Bang, which has proven highly sensitive in detecting sleep apnea in the general population (Chung et al., 2012). However, the STOP-Bang classified the risk for sleep apnea of participants with Down syndrome as low. This suggests that caregivers may underreport snoring and fatigue. As caregiver reports are thus poor predictors, it is recommended to use objective screening methods to detect sleep apnea.

To our knowledge, this is the first study that assessed the feasibility of the WatchPAT to detect sleep apnea in people with Down syndrome, a population at high risk for sleep apnea. By combing both quantitative and qualitative methods and including perspectives of people with Down syndrome themselves, caregivers, and clinicians, we could assess feasibility from multiple perspectives.

Several limitations to the study exist. First, we aimed for variety in level of intellectual disability when recruiting participants. However, after assessments of the participants, it turned out that participants with mild intellectual disabilities were underrepresented in our sample. Secondly, assessment of level of intellectual disability was only based on intelligence assessment and not on adaptive functioning. Thirdly, we did not compare WatchPAT data with polysomnography because polysomnography is invasive and rather burdensome for people with Down syndrome. For this reason, sleep apnea is underdiagnosed in people with Down syndrome (Yalamanchali et al., 2013). Nevertheless, applicability and validity of the WatchPAT have been investigated and compared to polysomnography in the general population and showed promising results (Jen et al., 2020; Yalamanchali et al., 2013).

Our study showed that the WatchPAT is a promising device to detect sleep apnea in people with Down syndrome. Compared to polysomnography, the WatchPAT is less invasive and less burdensome for this population. The WatchPAT can be used in the own environment that feels safe for people with Down syndrome. In addition, the WatchPAT is a relatively accessible solution to implement in care institutions. Clinicians need to interpret WatchPAT measurements frequently to become proficient, therefore it is recommended that not all clinicians in a care institution are trained, but this is delegated to a small group of clinicians. Acceptance of the WatchPAT could be improved by a few adjustments to the device, such as a smaller finger probe and making the watch more attractive. The WatchPAT represents a feasible alternative to polysomnography for detecting sleep apnea as respiratory indexes calculated using the WatchPAT are positively correlated with respiratory indexes obtained by polysomnography (Yalamanchali et al., 2013). Ideally, future studies should formally confirm this for people with Down syndrome as well. Consequently, the WatchPAT could be used as preferred detecting device in this population, limiting the use of polysomnography to second opinions or in-depth studies in complex cases.

Early detection of sleep apnea is important as complications of untreated sleep apnea include cardiovascular diseases, increased mortality, daytime sleepiness and impaired cognitive functioning (Simpson et al., 2018; Trois et al., 2009; Gimenez et al., 2021). Treating sleep disorders may improve cognition and quality of life in people with Down syndrome (Giménez et al., 2018). Furthermore, the presence of sleep apnea may result in earlier cognitive decline and may accelerate the progression of dementia (Chen et al., 2013; Gimenez et al., 2021) as sleep disruption increases amyloid accumulation due to increased production during wakefulness and decreased clearance in sleep (Mullins et al., 2020; Sharma et al., 2018). As literature showed that sleep apnea is highly prevalent in children with Down syndrome too (Chamseddin et al., 2019; Hsieh et al., 2019; Lee et al., 2018), it is recommended to develop a WatchPAT algorithm for children to enable even earlier detection of sleep apnea. This is important as sleep breathing disorders in children are associated with poor growth, cardiopulmonary complications and behavioral problems (Marcus et al., 1994; Mitchell & Kelly, 2006).

In conclusion, the WatchPAT is a promising device to detect sleep apnea in people with Down syndrome, as it is less invasive and less burdensome compared to polysomnography. In addition, the WatchPAT is a relatively accessible solution to implement in care institutions. A few adjustments to the device and providing enough time to caregivers may increase further acceptance. The WatchPAT could be used as preferred device for detecting sleep apnea in people with Down syndrome.

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CRediT authorship contribution statement

Manna A. Alma: Methodology, Validation, Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Rixt Nijenhuis-Huls:** Conceptualization, Funding acquisition, Methodology, Investigation, Formal analysis, Writing – review & editing. **Zarah de Jong:** Investigation, Formal analysis, Writing – review & editing. **Aurora M. Ulgiati:** Investigation, Resources, Data curation, Writing – review & editing. **Anja de Vries:** Investigation, Writing – review & editing. **Alain D. Dekker:** Conceptualization, Funding acquisition, Methodology, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration.

What this paper adds

Sleep problems are commonly reported in people with Down syndrome. Detecting sleep apnea in this population is difficult as polysomnography is time-consuming, costly and invasive. The WatchPAT can detect sleep apnea in a less invasive way. Surprisingly, feasibility of the WatchPAT has not been studied in people with Down syndrome so far. We used a combination of quantitative and qualitative research methods to study feasibility of using the WatchPAT. Our findings show that the WatchPAT is a promising device to detect sleep apnea in people with Down syndrome as two-thirds of participants accepted wearing the device. Younger participants and participants with mild/moderate intellectual disabilities were more likely to accept the WatchPAT. In addition, we found that sleep apnea was highly prevalent in our study population. Compared to polysomnography, the WatchPAT is less invasive and less burdensome for people with Down syndrome, among others because it can be applied in the own living environment that feels safe for people with Down syndrome. In addition, the WatchPAT is a relatively accessible solution to implement in care institutions. Possibly some adjustments to the device can increase further acceptance.

Declaration of Competing Interest

The authors declare no conflict of interest. The WatchPAT devices and hands-on training sessions were provided for free by Itamar Medical Ltd. for research purposes. Alliade independently designed, executed, analyzed and reported this study.

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