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Validation of a hand-mounted wearable sensor for scratching movements in adults with atopic dermatitis

To the Editor: Currently, itch is evaluated primarily through subjective surveys. Technologies used as objective measures of scratching, the natural reflex to itch, show variable levels of performance.[1] We recently reported the development of an advanced acoustomechanic wearable sensor (ADAM) that is able to detect acoustomechanic signals generated by scratching via the fingers or wrist in a pediatric cohort with atopic dermatitis (AD), with high accuracy.[2] Herein, we report the development of a new AI-algorithm that accurately quantifies scratching behavior and key sleep metrics on a single wearable device for adults with AD.

A cohort of healthy adult subjects performed scratch and non-scratch activities while wearing the ADAM sensor. The data were then used to develop an algorithm for scratch detection. Patients with AD were recruited and consented to monitor nocturnal scratching behavior at home by wearing the ADAM sensor on the dorsum of the dominant hand. Manually-annotated infrared camera footage was scored by 2 authors as the ground truth for scratch events. Sleep quality was analyzed using a modified sleep-monitoring algorithm published previously from wrist-mounted actigraphy systems.[3]

The number of hourly scratch events was determined for each sleep night by dividing the total number of scratch events by the patient's total sleep time (TST). We performed ANOVA and pairwise t-tests for key outputs across AD severity (mild, moderate, and severe).

A total of 11 adults participated with mild to severe disease (validated Investigator Global Assessment [vIGA] 2.5 ± 0.7). A total of 73 nights (457 total hours) were analyzed. When compared to visually-observed scratching via infrared camera, the new AI-algorithm detected scratch events with 93% sensitivity, and 100% specificity, with an average Fleiss kappa of 0.84 compared to manually-coded infrared camera outputs.[4] Scratch events per sleep hour increased from 0.6 to 4.6 and 12.6 for mild, moderate, and severe disease with all pairwise comparisons statistically significant (Fig 1).

When assessing the relationship between scratch events per hour and TST, there is a clear inverse correlation ($R = 0.69$). When comparing scratch events per night with TST, a similar inverse correlation is seen ($R = 0.54$). With increased scratch events per sleep hour, there is a direct correlation with increasing wake after sleep onset (WASO) ($R = 0.64$) (Fig 2).

Despite its prevalence and impact on quality of life, itch has proven technically challenging to measure accurately with wrist-mounted systems. The flexible and miniaturized nature of the sensor allows for dorsal hand placement to accurately capture both finger and wrist scratching. Given that itch's primary reduction in quality of life is driven by worsening sleep,[5] a single ADAM sensor is convenient in capturing both. Beyond utility for clinical trials, broader technology deployment to patients would enable costs that would resemble popular consumer fitness trackers. Additional software features may also link nocturnal scratch metrics to adherence, to medications, or changes in environmental conditions to empower patients and change behavior.

This study describes the development and validation of an advanced wearable sensor for the accurate assessment of scratching behavior and sleep in adult patients with AD. This technology may be useful as a clinical outcome assessment for conditions where itch is prominent.

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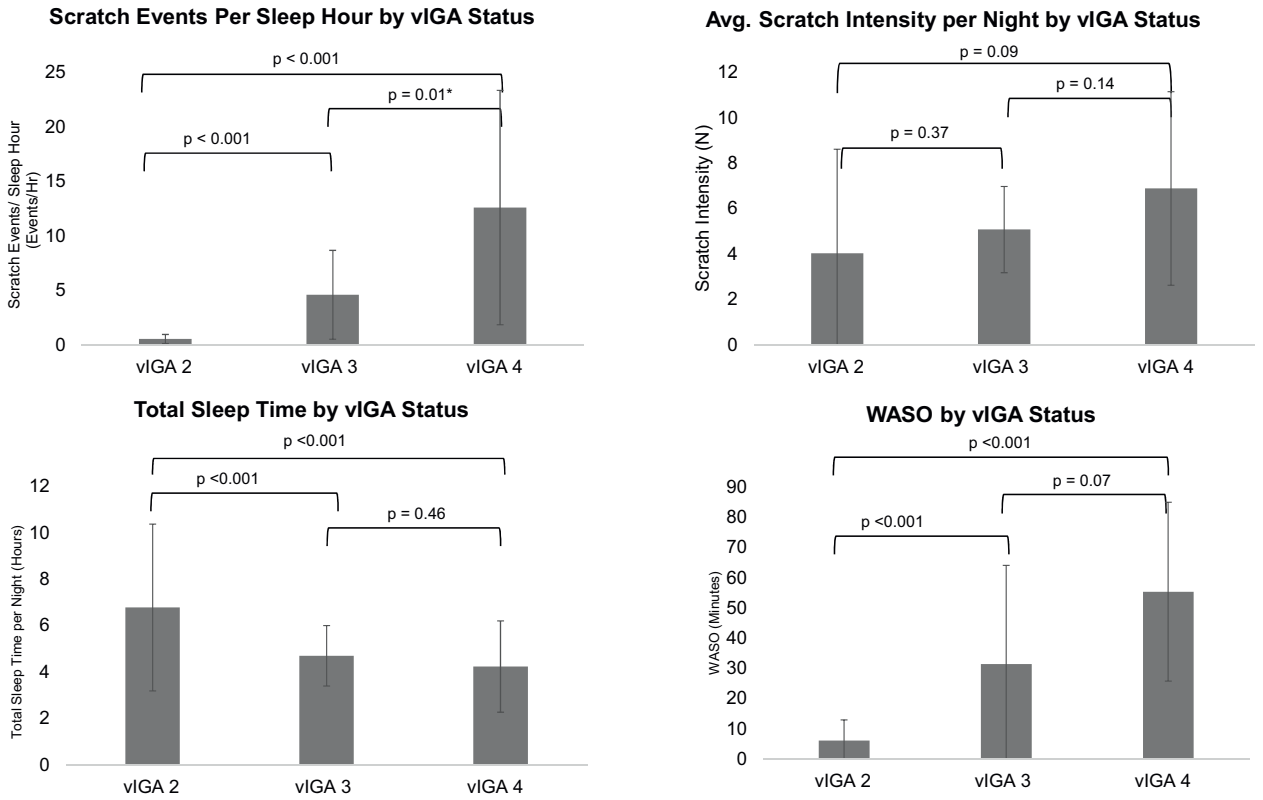

Fig 1. ***P*-value < .001. **P*-value < .01. Scratch events per sleep hour was computed for AD patients categorized by Validated Investigator Global Assessment (vIGA) status of 2, 3, or 4 across all sleep nights. Across all IGA levels, there was a statistically significant increase in scratch events per sleep hour. Average scratch intensity per night was computed for AD patients and categorized by vIGA status of 2, 3, or 4 across all sleep nights. With increasing vIGA scores, scratch intensity per night also increased. However, only scratch intensity per night for patients with vIGA 4 vs patients with vIGA 2 were noted to be statistically significant. Total sleep time in hours was computed for AD patients categorized by vIGA status of 2, 3, or 4 across all sleep nights. Total sleep time decreased with increased disease severity, although this was only statistically significant between vIGA 2 and 3, and vIGA 2 and 4. Wake after sleep onset (WASO) in minutes was computed for AD subjects categorized by vIGA status of 2, 3, or 4 across all sleep nights. The total amount of time spent awake after sleep onset increased with disease severity, with statistical significance between vIGA 2 and 3 and vIGA 2 and 4. *vIGA*, Validated Investigator Global Assessment; *WASO*, wake after sleep onset.

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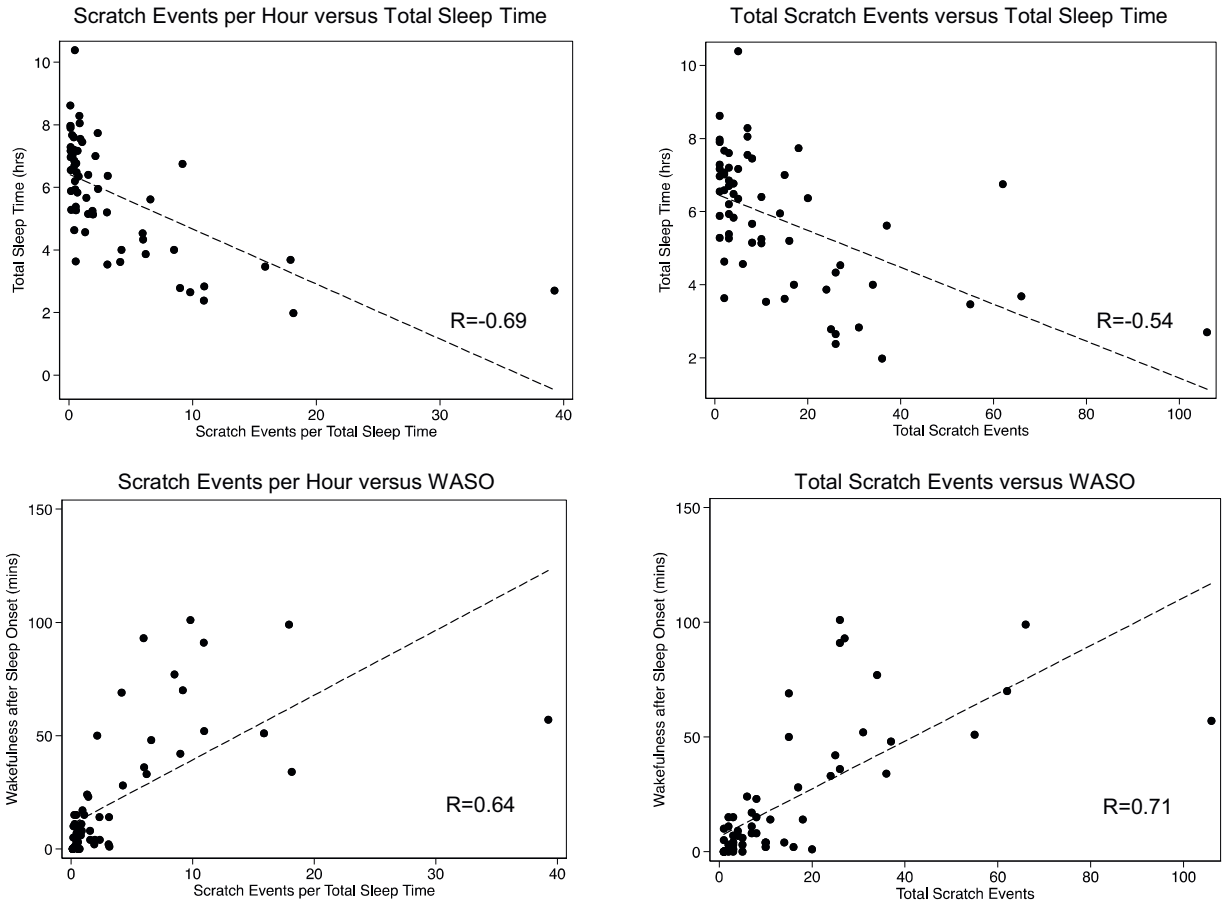

Fig 2. Greater number of hourly nocturnal scratch events was associated with reduced total sleep time (TST). Greater number of total nocturnal scratch events was associated with reduced TST. As the number of hourly nocturnal scratch events increase, the WASO increased. Greater number of total nocturnal scratch events was associated with increased WASO. *WASO*, Wake after sleep onset.

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All data needed to evaluate the conclusions in the paper are present in the paper and/or the Supplementary Information with publication. Individual participant data will not be made available to the public. Additional data related to this paper may be requested from the corresponding author upon reasonable request. Correspondence and requests for materials should be addressed to S.X.

Key words: atopic dermatitis; allergy; digital health; itch; medical device; pruritus; scratch; sleep; technology; wearable.

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Conflicts of interest

K.S.C, M.K., D.R.S., and S.X. are employees in Sibel Health, a private company with a commercial interest in the technology. K.O. and A.I. are employees in Maruho Co, Ltd, a private company providing funding. S.X. is an inventor on a patent application related to this work filed by USPTO (no. PCT/US2019/018318, filed on February 15, 2019). The authors declare no other competing interests.

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Clinical features and staging of mycosis fungoides of the eyelids: A retrospective cohort study

To the Editor: Mycosis fungoides (MF) may rarely cause ocular abnormalities, including eyelid involvement with various clinical features. However, the relationship between eyelid involvement and subtype or stage of MF was not well-documented previously.[1-5]

Among our 647 patients with nonerythrodermic MF (mean age, 44.1 years) who were followed up between 2003 and 2022 in a single tertiary center, eyelid involvement was recorded in 24 (mean age, 57.3 [26-92] years) patients (Table I). In the great majority of them, the diagnosis was determined via histopathologic examination performed from elsewhere other than the periorbital region. In our main cohort, 71.4% had classical, 7.4% folliculotropic, and 6.5% poikilodermatous types of MF, whereas in patients with eyelid involvement, these rates were 16.7%, 70.8%, and 12.5%, respectively. In 18 (75%) of them, eyelid involvement was associated with other lesions of MF located on the face. In 18 patients, eyelids were involved bilaterally. The upper portion of the eyelid was involved in all cases and 14 of them also showed the involvement in the lower portion of the eyelid. Eyelid MF was presented as persistent erythematous scaly patches or plaques ($n = 16$) (Supplementary Fig 1A, available via Mendeley at https://data.mendeley.com/datasets/bf2nrx8x2w/1) associated with excoriations in one of them, tumors of variable size ($n = 6$) some of them with ulceration (Supplementary Fig 1B, available via Mendeley at https://data.mendeley.com/datasets/bf2nrx8x2w/1), madarosis ($n = 4$), edema ($n = 4$), blepharitis ($n = 4$), eczematization ($n = 3$), poikilodermatous changes ($n = 2$), ectropion ($n = 2$), diffuse infiltration ($n = 2$), dyspigmentation ($n = 1$), atrophy, wrinkling ($n = 1$), and milia-like papules ($n = 1$). Although patients with advanced-stage (IIB, IVA, and IVB) constituted only 9.1% of the main cohort, this rate reached 75% in patients with eyelid involvement.

The incidence of ocular involvement of MF varies in a wide range of 2% to 37% in several reports primarily depending on the referral center or the study design and in most of them, the eyelids were emphasized as the most frequent site affected.[1-5] Our dermatology center-originated study focusing only on eyelid involvement of MF also showed a low rate (3.7%), which may have also been negatively affected by the exclusion of patients with erythroderma.

Periocular involvement of MF has been reported to be more common in older ages and shows advanced-stage disease, similar to that of our group.[1-5] Erythematous scaly lesions were the most common presentation of eyelid involvement of MF in our series, followed by tumors. In addition, poikiloderma of eyelids because of MF seen in 2 cases was a remarkable finding.[1-5]

The distribution of the subtypes of MF showed major variations between our main cohort consisting predominantly of classical MF and the group with eyelid involvement of whom a great majority (70.8%) had folliculotropic MF. However, most of these patients had erythematous patches and plaques on eyelids indistinguishable from lesions in patients with classical MF on other sites, whereas more typical folliculotropic MF lesions, such as excoriation, milia-like papules, diffuse thickening, and madarosis, were encountered in only a few cases.

Tumors observed in 25% of patients indicated the eyelid as an important location of these specific advanced-stage MF lesions. Furthermore, the high rate (75%) of advanced-stage disease in the eyelid involvement group revealed the question of whether this correlation may have a prognostic significance.

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