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Review

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Application of ecological momentary assessment in stress-related diseases

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Abstract

Many physical diseases have been reported to be associated with psychosocial factors. In these diseases, assessment relies mainly on subjective symptoms in natural settings. Therefore, it is important to assess symptoms and/or relationships between psychosocial factors and symptoms in natural settings. Symptoms are usually assessed by self-report when patients visit their doctors. However, self-report by recall has an intrinsic problem; "recall bias". Recently, ecological momentary assessment (EMA) has been proposed as a reliable method to assess and record events and subjective symptoms as well as physiological and behavioral variables in natural settings. Although EMA is a useful method to assess stress-related diseases, it has not been fully acknowledged, especially by clinicians. Therefore, the present brief review introduces the application and future direction of EMA for the assessment and intervention for stress-related diseases.

Introduction

Many physical diseases have been reported to be associated with psychosocial factors such as irritable bowel syndrome (IBS) [1], primary headaches [2], and asthma [3]. In these diseases, assessment relies mainly on subjective symptoms in natural settings. Therefore, it is important to assess symptoms and/or relationships between psychosocial factors and symptoms in natural settings.

Symptoms are usually assessed by self-report when patients visit their doctors. Most self-reported data are collected by questionnaires or interviews that ask patients to summarize past symptoms over some period of time. For example, a pain questionnaire might ask about the intensity of last week's pain. However, self-report by recall has an intrinsic problem; "recall bias". Many research data have shown that people are not be able to accurately recall past experience, particularly experiences that are frequent, mundane, and irregular, because self-report data are affected by recall biases such as their mood states (state biases) (Table 1) [4]. In addition to the state biases, there are other recall biases affecting self-report data: (1) recency, which means that more recent events are more accessible to memory, (2) saliency, which means that salient experiences are more likely to be encoded and subsequently recalled, (3) effort after meaning, which means that people's natural and unconscious tendency is to reconstruct events so as to make them consistent with subsequent events, (4) participants' misunderstanding of questionnaire instruction sets that require them to aggre-

Table 1: Recall biases affecting self-report data

State biases
Recency
Saliencey
Effort after meaning
Misunderstanding of instruction set
Aggregation

gate and summarize their experience in the recent past, and (5) aggregation, which is cognitive processing that is necessary to respond to questions about the occurrence or frequency of events or about their average or typical characteristics [5]. In fact, there have been some studies that show inconsistency between recalled symptoms and momentary recorded symptoms [6-8]. Especially, previous studies indicated that variability of symptoms could affect the recall (Table 2) [7,8].

Ecological momentary assessment (EMA) has been proposed as a reliable method to assess and record events and subjective symptoms as well as physiological and behavioral data in natural settings [9]. Recently, Burton et al. [10] reported an excellent systematic review of electronic diaries for self-report data such as pain and symptoms. In addition, Smyth and Stone [11] made a fabulous review of EMA research in behavioral medicine showing some examples including objective data such as cortisol in healthy people and peak expiratory flow in asthma patients. However, little attention has been paid to physical activity recorded objectively in the context of EMA research, although some studies using physical activity as an EMA variable have been published. Therefore, in the present brief review, we would like to introduce EMA and its usefulness, especially physical activity data as an object variable in EMA. In addition, we would like to discuss future applications of EMA for intervention in lifestyle-related physical diseases such as obesity and diabetes mellitus.

Ecological momentary assessment (EMA)

EMA is a sampling method developed 'to assess phenomena at the moment they occur in natural settings, thus maximizing ecological validity while avoiding retrospective recall' [9]. When applying EMA to stress-related diseases such as IBS and asthma, paper-and-pencil diaries have often been used as recording devices [12,13]. However, such diaries have the disadvantage of 'faked compliance', i.e. disguise of compliance by recording data at times other than those designated even if signaling is used to remind patients of recording data [14-16].

To overcome this 'faked compliance', computerized EMA, i.e. EMA using computers as electronic diaries, has been developed. In computerized EMA, the input time is also recorded by the device in order to avoid faked compliance [17]. In addition, electronic diaries are able to issue randomly scheduled prompts to solicit data entry, thus reducing the risk that the assessment schedule may affect a natural rhythm in patients' lives [17].

Electronic diaries have been often implemented in palm-size computers [18-20] or watch-type computers (Fig. 1) [8,21] while an electronic touch-tone telephone system has been also used as a validated system [22]. The details of proposed guidelines and designing protocols for EMA are beyond the scope of the present report and have been described in previous reports [17,23,24].

Analysis of EMA data

Generally, the structure of momentary data is complex. Most time-series data tend to show serial autocorrelation, which violates the assumption of independence underlying parametric statistical methods such as multivariate regression. In addition, repeated measures of analysis of variance (RM-ANOVA), a well-known technique for analyzing data collected over time, cannot be applied to the analysis of most real-time data because the assumption underlying the strict data structure required by RM-

Table 2: Consistency between recalled headache intensity and momentary headache intensity for the two subgroups of patients with tension-type headache

	low SD group		high SD group	
	Mean (SD)	ICC (A, 1) (95% C.I.)	Mean (SD)	ICC (A, 1) (95% C.I.)
Recalled headache intensity and	54.7 (22.5)		59.5 (17.8)	
mean headache intensity of all recordings	41.3 (23.2)*	0.75 (0.04, 0.93)	33.5 (16.8)*	0.21 (-0.11, 0.56)
mean headache intensity of scheduled recordings only	41.1 (22.4)*	0.75 (0.00, 0.93)	29.2 (16.2)*	0.16 (-0.09, 0.48)
mean headache intensity of event-contingent recordings only	60.3 (23.0)	0.81 (0.41, 0.95)	66.8 (12.2)	0.21 (-0.22, 0.60)
mean headache intensity of recordings when headaches were present	44.7 (19.0)*	0.77 (0.24, 0.92)	40.5 (13.0)*	0.29 (-0.11, 0.65)
maximal headache intensity of all recordings	71.5 (19.0)*	0.64 (-0.08, 0.89)	83.0 (11.7)*	0.23 (-0.10, 0.59)

ICC (A, 1), intraclass correlation coefficient of absolute agreement; SD, standard deviation; C.I., confidence interval.
* $P < 0.001$, vs. recalled headache intensity.
Recalled headache intensity was compared with some indices of momentary headache intensity.
High SD group is a group of patients whose headache intensity was highly variable.

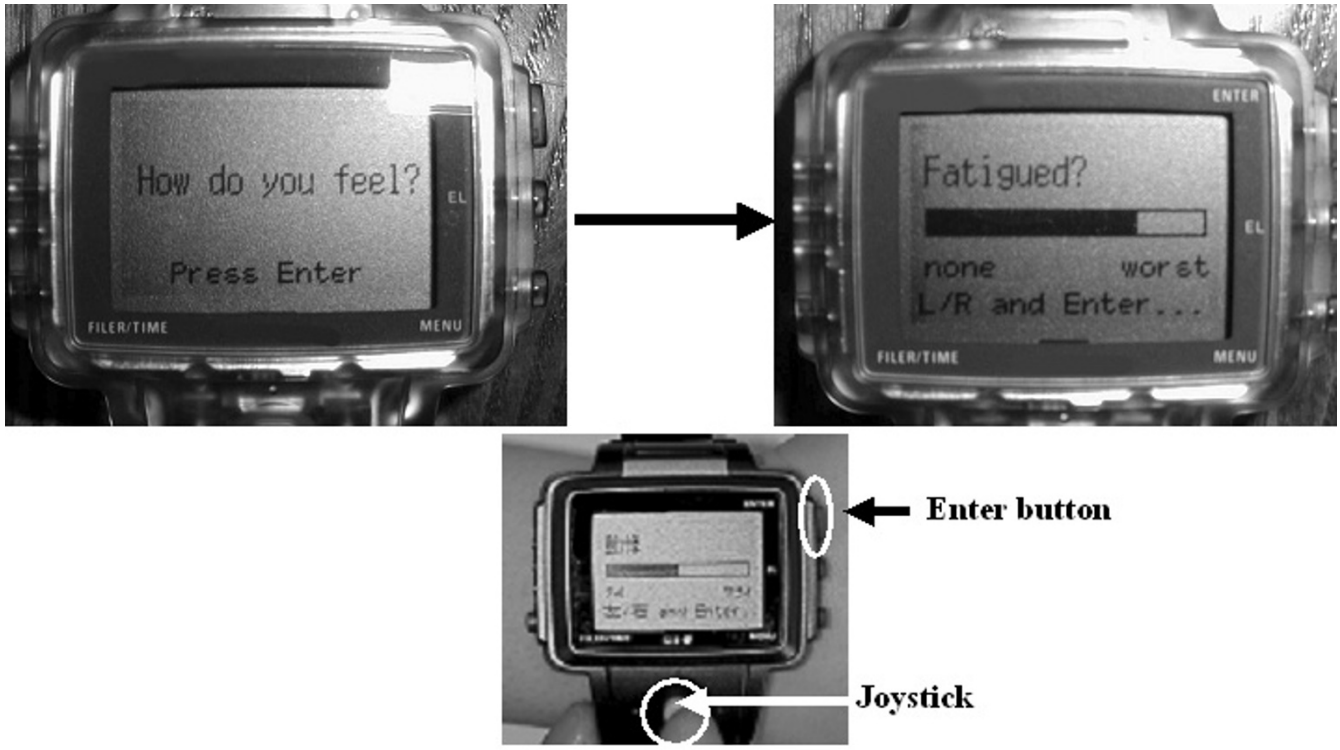

Figure 1
The watch-type computer device used in previous studies [8,20,55,57]. It is easy to manipulate the device using the joystick to lengthen or shorten the bar-like visual analogue scale and to push the enter-button to record the scale.

ANOVA are mostly not met, which includes equally spaced data and no missing data. In contrast, multilevel modeling is able to deal with many characteristics of momentary data collected by EMA [25]. A comprehensive step-by-step lecture for analyzing real-time data using multilevel modeling was described in a previous report by Schwartz [26].

Previous studies using EMA in stress-related diseases

Assessing self-report symptoms

There have been many studies using EMA to assess subjective symptoms in stress-related physical diseases. Most studies assess pain in pain-related physical diseases such as rheumatoid arthritis, fibromyalgia and headaches [18-20,27-39]. Fatigue has also been evaluated using EMA in many studies [21,40-45] because pain and fatigue are difficult to assess objectively. Eating disorders are also major problems to be handled, and there have been some studies using EMA to assess symptoms in patients with bulimia nervosa or with binge eating disorder in natural settings [46-54] although there have been few studies on anorexia nervosa. Recently, attempts have been made to apply EMA to other stress-related physical diseases such as IBS [55].

Assessing subjective symptoms and objective data using wearable devices

Recently, there have been some studies, but not many, using wearable devices for assessing and recording objective data as well as subjective symptoms in natural settings. Kamarck et al. [56] showed, using electronic diaries and ambulatory blood pressure monitoring, that daily psychosocial demands caused elevation of ambulatory blood pressure. Smyth et al. [57] reported the association between psychological stress and salivary cortisol secretion. Saito et al. [58] reported that chemical substances in the air caused subjective symptoms in patients with multiple chemical sensitivity using electronic diaries and wearable gas-samplers in natural settings. Affleck et al. [59] and Smyth et al. [60] reported that peak expiratory flow rate was associated with psychosocial factors in asthma patients using peak flow meters. In addition, there have been some recent studies [61-64] assessing the relationship between subjective symptoms and physical activity using actigraphy in natural settings. These previous studies using actigraphy have also successfully yielded many novel findings.

In our recent study [61], for example, watch-type wearable computers equipped with an actigraphy inside were used

for recording momentary headache intensity and physical activity simultaneously (Figure 1). The results of the study showed objectively that there were significant negative associations between headache intensity and the simultaneous and subsequent activity level, and that activity level was significantly reduced at headache exacerbations (Figure 2). There have been few devices that are able to collect long-term objective data noninvasively in natural settings. Therefore, actigraphy is one of the most useful devices for EMA research at this point.

Future direction

Because recent studies using actigraphy show significant findings by applying sophisticated time-series data analyses [65-68], more attention should be paid to objectively assessed and recorded data such as locomotor activity and behavior in natural settings. In addition, autonomic nervous function has been reported to be impaired in patients with psychosomatic disorders [69-71]. Therefore, in the near future, studies should be performed for longer duration, i.e. a few years [72], using wearable devices to simultaneously collect behavioral data, locomotor activity, and physiological data as well as subjective symptoms [73,74].

In addition, one future application of EMA is a tool for intervention in lifestyle-related physical diseases such as obesity and diabetes mellitus. In psychiatric diseases such as anxiety disorders, there have already been some studies [75-77] on computerized cognitive behavioral therapy (CCBT) using palm-size computers, although the efficacy of CCBT has not been confirmed. In addition, internet-based intervention has been reported to be effective in lifestyle-related diseases such as obesity [78,79] and diabetes [80]. However, there have been few studies on the effect of behavioral change programs or CCBT using palm-size computers, which could provide timely feedback or intervention in natural settings. Therefore, application of EMA technique to intervention in lifestyle-related diseases should be conducted in the near future.

Conclusion

Computerized EMA will be able to yield more fruitful findings about the relationships between psychosocial factors and stress-related diseases when wearable devices are developed to assess and record more physiological and behavioral data in natural settings.

List of abbreviations used

IBS: irritable bowel syndrome; EMA: ecological momentary assessment; CCBT: computerized cognitive behavior therapy.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KY, YY, and AA wrote and approved the final manuscript.

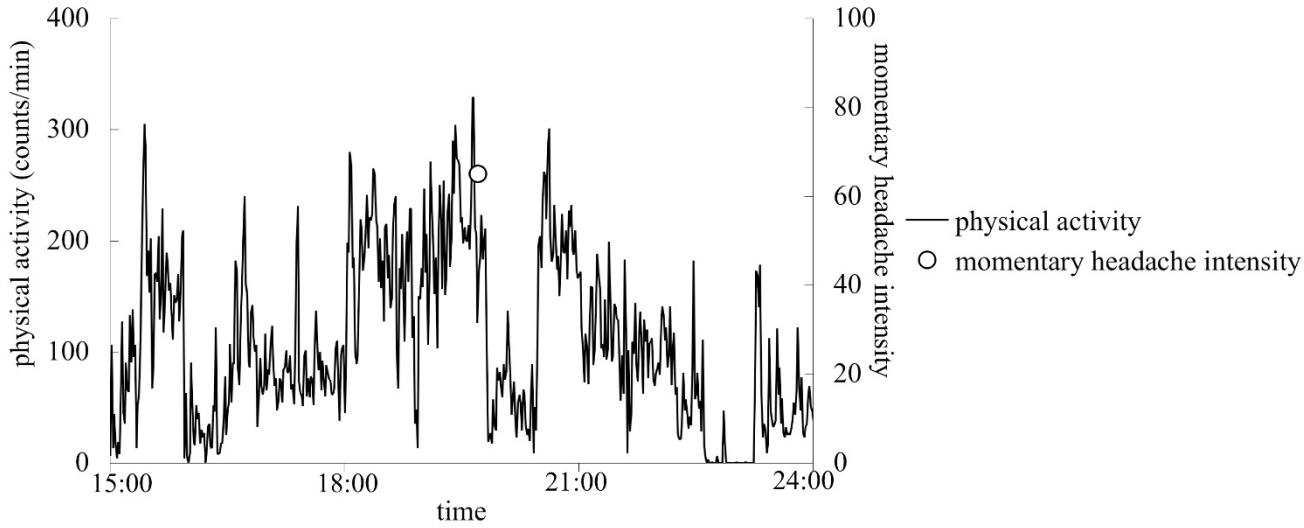

Figure 2

Example of data for momentary headache intensity and physical activity of a patient with tension-type headache [57]. Line graph shows physical activity counts per minute. Open circle shows momentary headache intensity. Headache was exacerbated and the patient added an event-contingent recording around 19:30 (open circle). It seems that physical activity was decreased after the headache exacerbation.

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