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Analyzing Change Processes Resulting from a Smartphone Maintenance Intervention Based on Acceptance and Commitment Therapy for Women with Chronic Widespread Pain

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ABSTRACT

Purpose

This study investigated change processes resulting from a randomized controlled trial smartphone-delivered maintenance intervention with daily electronic diaries and personalized written feedback based on acceptance and commitment therapy (ACT) following a rehabilitation program for patients with chronic widespread pain.

Method

This study included 48 women who during a 5-week period completed electronic diaries three times daily, totaling 3372 entries. In response to the completed diaries, they received daily feedback from a therapist for 4 weeks (excluding weekends), totaling 799 feedback messages. To analyze the change processes, we explored the associations between feedback and daily ratings of participants' physical activities, positive emotions, pain fear and avoidance, pain acceptance, and self-management. Commitment to physical activities and the participants' evaluation of feedback were also analyzed. Multilevel models were used in the statistical analyses.

Results

Participants' average pain fear and avoidance decreased over the intervention period (mean -0.019 , $P = 0.05$). Self-management, pain acceptance, and positive feelings increased (mean -0.030 , $P < 0.01$; mean -0.015 , $P < 0.01$; and mean -0.011 , $P = 0.01$, respectively). Participants' performance of physical activities decreased slightly over time, but the level of commitment was high and they evaluated the feedback as supportive for staying sufficiently active. No correlation between diary contents and feedback messages was found, even though most of the participants evaluated the feedback as supportive.

Conclusion

No support was found for an association between diary content and feedback based on ACT. However, diary measures were consistent with the ACT model and may have influenced positively the change processes.

INTRODUCTION

Recommended treatments of chronic widespread pain (CWP) involve multidisciplinary approaches because of the complex pathophysiological mechanisms of this disease combined with social and psychological factors [1, 2]. These treatments include graded physical exercises, pharmacological treatment, and cognitive behavioral therapy (CBT), often provided within the frame of multidimensional rehabilitation [3–5]. Although the short-term effects (up to 1 year) of such treatments have been well demonstrated, interventions to support the maintenance of effects and avoid relapses are needed [3]. For treatment and/or maintenance treatment of CWP, an alternative may be internet-based CBT and smartphone interventions [6, 7]. Such technology-supported interventions are increasingly used to support people with health problems including chronic pain in self-management, and show effects similar to those of face-to-face CBT [8–15]. Studies that have used additional methods of communicating with participants, such as short message service (SMS), suggest that they appear to be even more effective in supporting behavioral change [16].

A relatively recent development within CBT with strong empirical support is acceptance and commitment therapy (ACT). The objective of ACT is to improve functioning and quality of life by increasing psychological flexibility (PF) [17–19], which is defined as the ability to act in accordance with long-term goals and values also in the presence of interfering pain and distress. In the ACT treatment model, PF comprises subprocesses such as acceptance, defusion, values orientation, committed actions, present moment awareness, and self as context [20, 21]. ACT shares important features with CBT, such as behavior activations, although acceptance and cognitive defusion strategies may be relatively unique to ACT [20, 22]. A number of studies based on ACT have demonstrated effects related to the improvement of health outcomes in patients with chronic pain [18, 23–26], including internet-based interventions [27–29]. Studies have also investigated the impact of the different treatment components of ACT [26], as well as mediators of change, supporting the importance of both ACT-consistent interventions and changes in processes related to PF [18]. However, to our knowledge, no study has investigated the change process of the core components of ACT resulting from a smartphone intervention.

The current study builds upon a randomized controlled trial (RCT) of a smartphone maintenance intervention (SMI) with electronic diaries and written feedback from a therapist based on an ACT model to support women with CWP after completing a 4-week rehabilitation program [28, 30].

The aim of the present study was to investigate the change processes resulting from the SMI. For this purpose, the associations between daily electronic diary content and daily written personalized feedback were analyzed based on the following research questions.

1. Did participants' daily planned and performed physical activities, positive feelings, pain acceptance, and self-management increase during the intervention period? Were these changes related to the daily feedback?

2. Did participants' pain-related fear and avoidance and catastrophizing decrease during the intervention period? Were these changes related to the daily feedback?
3. Were participants committed to and satisfied with their planned physical activities?
4. How did the participants evaluate the daily individualized feedback?

MATERIALS AND METHODS

Design

The design was a two-arm RCT. All participants completed a 4-week inpatient multidimensional rehabilitation program for chronic pain including education and pain management in a cognitive setting, various forms of aerobic exercises, stretching, myofascial pain treatment, relaxation, and medication as needed [31]. In the fourth week of the rehabilitation program, participants were randomized to one of the two study arms: experimental group or control group. The experimental group received 4 weeks of SMI. The main elements of the SMI were a personal meeting, daily electronic diaries, and individualized written situational feedback.

In the personal meeting, each participant was informed about the intervention and asked about her functioning, goals for health-related behavior, and needs for support. Values and value-based activities were discussed and the patient received two written value-based exercises to take home. The participant was lent a smartphone and made the first diary entry at the meeting. The therapist received a summary of this first meeting.

The participants were asked to complete electronic diaries three times per day (morning, midday, and evening) for 5 weeks. The primary objective during the first week of completing diaries was to familiarize the participants with the technology. The diaries included 16 to 24 questions about planned and performed physical activities (i.e., mild exercise, stretching, resting, aerobic exercise, pleasurable activity), satisfaction with performed activities, thoughts, feelings, sleep, pain level, pain-related fear and avoidance, pain catastrophizing, pain acceptance, pain self-management, and evaluation of the feedback (Table 1). All diaries included a comment field giving participants the opportunity to write a short personal message to the therapist. If the diary entry was not returned within 45 min, the server automatically sent an SMS reminder message. Two reminders within 1 h per diary were allowed. The submission of the diary was only possible when it was fully completed within 90 min. Then, the diary was closed.

[TABLE 1]

For 4 weeks (excluding weekends) after returning home, participants received daily written feedback messages written by one of three therapists trained in ACT. The feedback messages were individualized and tailored to the participant's situation as reported in the diary, based on the summary of personal information given at the personal introductory meeting (i.e., family situation and health-related goals) and formulated in accordance with the ACT protocol developed for the study [32] focusing on values, value-based behavior, mindfulness, and acceptance. The protocol was based on ACT for chronic pain [22, 33, 34]. All ACT processes (values,

committed action, contact with the present moment, cognitive defusion, and acceptance) were present in each of the 4 weeks, but with a different focus. The first week was used to introduce the ACT processes, and the following weeks were used to reinforce the given information, to go gradually in depth, and to stimulate the practice of exercises related to the ACT processes [32]. Despite the existence of a protocol, the therapist had the freedom to evaluate and choose the ACT component(s) that suited the participant at that specific moment. In addition, the therapists were instructed to be empathic, include positive reinforcement, information, metaphors, and ACT exercises. The instructions for the exercises were written directly in the feedback or the feedback referred to exercises available on the mobile phone and/or the website. The therapists also had access to each other's responses. The feedback was intended to support and stimulate self-management and to encourage mindfulness and a willingness to engage in meaningful activities to promote behavioral change (see Textbox 1 for examples of the feedback). The feedback messages were available 90 min after participants completed the midday diary during weekdays and were mainly based on the last three submitted diaries (the evening diary from the day before and the morning and midday diaries from the same day). Feedback was sent even if the midday diary was not submitted; then information from the last submitted diary was used. An SMS was sent to signal that feedback was available. The SMS included a link to the website where the feedback was posted. There was no limitation to the length of the feedback, which varied from a few sentences to a few paragraphs.

Textbox 1: Example of a feedback message

Hi. Congratulations on having managed to complete the four week intensive treatment at the rehabilitation center.

I suggest that you use a few minutes to think about how it feels to be finished with your stay at the rehabilitation center? What has changed? What is the most important thing that you have learned? Is there anything that you learned that you weren't sure you would manage to cope with? Now you are going towards a life with less pain and more activity - you've probably already changed some health habits - the challenge in the coming weeks will be to apply what you have experienced as useful at the rehabilitation center in everyday life at home. Especially now in the beginning, this will require some effort, but eventually it will become an established habit and will feel much less demanding.

It seems that you have planned an active day today, great that you also get to rest for a while and perform relaxation exercises in between. It does not seem like you have negative thoughts related to your pain now. It seems that it is you who decides what you do and your decision is not influenced by your pain experience. That's positive! Have a nice afternoon together with your daughter and friends. Regards Mary

All participants received login information to a noninteractive website with information on coping strategies for people with chronic pain. The website also included four audio files with mindfulness exercises (e.g., focused breathing, awareness of thought content).

See Appendix Table 6 for more detailed information of the RCT.

In the current study, only data from the intervention group, the diaries, and the feedback were analyzed.

Sample

The analyses of the present study are based on data from participants who were randomized to the treatment condition (48 women; Table 2) in a previously reported RCT [28]. Data consisted of de-identified daily diaries (3372 entries) and written feedback (799 messages).

[TABLE 2]

ASSESSMENT OF DAILY DIARIES

Physical Activities

The daily diaries had a list of activities to choose from for planned activities (morning and midday) and executed activities (midday and evening). Both planned and executed activities included low-level activity (horizontal exercises, relaxing, and stretching), medium-level activity (exercise in slow tempo), and high-level activity (aerobic exercise). The variables constructed were planned activity (low = PLA, medium = PMA, and high level = PHA) and executed activity (low = ELA, medium = EMA, and high = EHA). All responses were coded as 1 or 0. The activities were analyzed as dependent variables to measure change over time. All types of activities were analyzed separately, as was the time of delivery throughout the day (morning, afternoon, and evening). Furthermore, all activities of each type on each day were added to measure the total.

Evaluation of Performed Physical Activities (EPA)

By analyzing this variable as a dependent variable, it was possible to ascertain how the participants' satisfaction with physical activities varied over time. The scale responses were coded from 0 (very satisfied) to 4 (very dissatisfied) (Table 1).

Commitment to Physical Activities

By using the executed activity as dependent variable and planned activity as an independent variable in predicting the activity, it was possible to measure the patients' commitment.

Pain Catastrophizing (PC)

Three statements from the Pain Catastrophizing Scale (PCS) were included in the random diary with five possible answers from 0 (strongly agree) to 4 (strongly disagree), i.e., the higher the score, the more the participants disagreed with the PC statements indicating less catastrophizing thoughts. The independent variable representing PC was a sum score from these three questions (Table 1). By analyzing PC as a dependent variable, it was possible to evaluate how the participants' PC varied over time.

Pain Acceptance (PA)

The statement "Right now I feel my life is going well, even though I have chronic pain", an item taken from the Chronic Pain Acceptance Questionnaire (CPAQ) [35], represented pain acceptance. A five-point Likert scale measured the responses from 0 (strongly agree) to 4 (strongly disagree), i.e., the lower the score, the more the patient agreed with the statements. By analyzing this statement as a dependent variable, it was possible to evaluate how the participants' pain acceptance varied over time.

Pain Fear and Avoidance (PFA)

Four statements represented pain fear and avoidance (Table 1). A five-point Likert scale measured the responses from 0 (strongly agree) to 4 (strongly disagree), i.e., the lower the score, the more the participant agreed with the statements. By analyzing the sum of the scores of these statements as a dependent variable, it was possible to evaluate how the participants' pain fear and avoidance varied over time.

Pain Self-Management (PSM)

Five statements represented pain self-management (Table 1). A five-point Likert scale measured the responses from 0 (strongly agree) to 4 (strongly disagree), i.e., the lower the score, the more the patient agreed with the statements. By analyzing the sum of the scores of these statements as a dependent variable, it was possible to evaluate how the participants' pain self-management varied over time.

Positive Feelings (PF)

Five statements represented positive feelings, e.g., "right now, I am grateful". A five-point Likert scale measured the responses from 0 (strongly agree) to 4 (strongly disagree), i.e., the lower the score, the more the participant agreed with the statements (Table 1). By analyzing the sum score of these statements as a dependent variable, it was possible to evaluate how the participants' positive feelings varied over time.

Evaluation of Feedback

Participants' evaluation of feedback was also investigated. Each evening the participant could choose from a list of six statements (Table 1); it was possible to choose all or to submit the diaries without answering these questions. In the first 6 days, participants were at the rehabilitation center and did not receive feedback messages. Therefore, the first week and the weekends were not included in the analyses of these variables.

Assessment of Feedback Messages

In a previous study, the feedback messages were qualitatively analyzed based on an ACT and communication framework and a coding scheme/system was created [32]. Twelve codes were identified; five codes were related to an ACT model, and seven codes were related to motivation and communication strategies. The ACT model codes were Values (V), Committed Action (CA), Present Moment (PM), Acceptance (AC) and Cognitive Defusion (CD). The motivation and communication codes were Behavioral Support (BS), Advice (Ad), Empathic Statements (ES), Stimulate Participation (SP), Creative Communication (CC), General Information (GI), and Educational Information (EI) (examples are given in Appendix 2) [32].

The previously developed coding scheme was used in the present study making it possible to include the feedback messages in the statistical analyses. All possible ACT codes (V, CA, PM, AC, and CD) and all possible motivation and communication codes (BS, Ad, ES, SP, CC, GI, and EI) were included in the analyses as independent variables to measure their impact on the variables from the daily diaries. Furthermore, three new feedback variables were created: variable "A," condensing all ACT codes; variable "M," condensing all motivation and communication codes; and variable "AM," condensing all feedback codes. The intention was to subsequently measure the impact on the daily diaries of the entire

ACT content, the entire motivation and communication content, and all feedback messages.

STATISTICAL PROCEDURES

As noted, the data from this study were collected up to three times daily over 4 weeks featuring repeated measurements. For this type of data, multilevel modeling (MLM) is recommended because of its well-documented advantages over other statistical methods [36]. For internal consistency analysis, the ordinal reliability test was applied. The ordinal alpha estimates reliability more accurately for ordinal item response data (i.e., PC, PFA, and PSM) than alternative methods [37]. For this study, the variables were analyzed using MLM with the intercept and time slope as covariates, both as fixed and random effects. All calculations were performed using the R statistical program. For the mixed models, the lme multilevel package was used; for internal consistency analysis, the Rcmdr, psych, and GPArotation packages were used [38]. Correction for multiple testing was done using the Bonferroni test [39]. In the course of the study, there were no dropout cases. For each of the results described below, the code was run as a stand-alone analysis, differing in the number of covariates and thus the results do not interact with each other.

RESULTS

After correction for multiple tests, no correlation was found between the diary content and the specific elements of the feedback messages. Thus, details of these analyses are not included in this paper.

Physical Activities

To measure how physical activities evolved over the intervention period, the variables that represent the planned low-level activity (PLA) were added together and treated as a single untransformed variable. Analyzing PLA as a dependent variable resulted in a parameter estimate for time of -0.029 ($P < 0.01$), which indicates that the decrease of this activity over time was statistically significant. The same procedure was applied for the analysis of the other planned activities (PMA and PHA) and executed activities (ELA, EMA, and EHA). In five out of six models, the time effect was statistically significant but negative for all models, which indicates that activities diminished over time (Table 3).

[TABLE 3]

Evaluation of Performed Physical Activities (EPA)

The participants' own satisfaction with their physical activities was studied. For this variable, no transformation was applied. In this case, lower values of the dependent variable represent more satisfaction with activities; the parameter estimate for time was negative (-0.012) and statistically significant ($P < 0.01$), showing that over time the participants became more satisfied with their physical activities (Table 3).

Commitment to Planned Activities

By using the planned activities as a covariate to the performed activities, it is possible to study participants' commitment to their physical activities. The results show positive parameter estimates for time ($P < 0.01$; Table 4), confirming that participants were committed to their planned activities (Figs. 1, 2, and 3).

[TABLE 4]

[FIG. 1]

[FIG. 2]

[FIG. 3]

Pain Catastrophizing (PC)

The internal consistency for the PC items was acceptable (ordinal alpha coefficient = 0.79). By using the sum of the PCS score as the dependent variable, its dynamics could be evaluated. The parameter estimate for time was positive (0.004), which means that as time passed, participants disagreed more with the PC statements indicating a reduction in catastrophizing thoughts over time, although changes were not statistically significant ($P = 0.46$) (Table 3).

Pain Acceptance (PA)

By modeling the untransformed pain acceptance as the dependent variable, it is possible to verify how it changed over time. This variable has lower values the more the patient agrees with the pain acceptance statement (“Right now I feel my life is going well, even though I have chronic pain”). The parameter estimate for time was negative (-0.011 ; $P = 0.01$), showing that PA increased significantly over time (Table 3).

Pain Fear and Avoidance (PFA)

The internal consistency for PFA items was acceptable (ordinal alpha coefficient = 0.78). This variable was analyzed after recoding one out of four items (0 = strongly disagree to 4 = strongly agree). This item was inverted for the data collection. Lower values indicate lower PFA. The parameter estimate for time was negative (-0.019 ; $P = 0.05$), showing that PFA significantly diminished over time (Table 3).

Pain Self-Management (PSM)

The internal consistency for PSM items was acceptable (ordinal alpha coefficient = 0.68) [40–42]. This variable was analyzed after recoding four out of five items (0 = strongly agree to 4 = strongly disagree). These items were inverted for the data collection. PSM was analyzed over time and a decrease in values indicates an increase in self-management. The parameter estimate for time was negative (-0.030 ; $P < 0.001$), showing a statistically significant improvement in PSM over time (Table 3).

Positive Feelings (PF)

The positive feeling variables were also analyzed over time after recoding three out of five variables. Lower PF values indicate participants’ stronger agreement with the PF statements. Results showed a negative parameter estimate for time (-0.015 ; $P < 0.001$), indicating that positive feelings increased significantly over time (Table 3).

Participants’ Evaluation of Feedback

Table 5 and Fig. 4 show that most of the participants who responded to the evening diaries chose one item of evaluation of the feedback messages almost every day. In

the final days of the intervention, the number of participants who answered the evening diaries decreased. The feedback evaluation that was most often marked was “The feedback has helped me to stay sufficiently active” (mean, 26 %); the feedback message that was least often marked was: “The feedback has helped me to be aware of my coping strategies” (mean, 6 %) (Table 5).

[TABLE 5]

FIG. 4

DISCUSSION

The analyzed content of the diaries is presented in Table 1 and starts with physical activities. Our results show that both planned and executed activities decreased slightly over time (Table 3). Figures 1, 2, and 3 illustrate that the level of activity decreased slightly after the first week but remained stable during the next weeks. To interpret these results, it is fundamental to know that at the rehabilitation center, the patients had an intensive physical activity level [28, 31] and the challenge was to continue to stay active in their daily life after the rehabilitation period. Due to the high level of activities performed at the rehabilitation center, it was expected that the level of activities would decrease at home. The results also show that participants were committed to performing their planned physical activities. This suggests that the objectives of the intervention—that participants should stay sufficiently active at home—were achieved. This is also in line with participants’ evaluations of feedback messages, as they most often reported that the feedback had helped them to stay sufficiently active (Table 5 and Fig. 4). One of the main components in chronic pain treatment is to stimulate physical activity and many studies show effective results from doing so [3, 4]. To our knowledge, no studies have focused on how to stimulate women with CWP to stay suitably physically active after a rehabilitation period. The intervention presented here may thus represent an alternative. Future studies with an RCT design are necessary to confirm the obtained results.

Interestingly, although reduction in PC was seen in the previously reported RCT [28], similar changes in catastrophizing were not evident in the present study (Table 3). This may be due to differences in the methodology used to assess PC in these two studies: in [28], the PCS containing 13 items was used [43]; in the diaries (the present study), PC was assessed using three items from the PCS. However, the lack of a significant reduction in catastrophizing corresponds with previous mediation analyses, in which data indicated that catastrophizing may not be a central change process in ACT-based treatment [18].

Regarding pain acceptance, the results show a statistically significant increase over time (Table 3). This result supports the findings from the RCT study where PA increased after the intervention period, as well as findings from earlier research illustrating that ACT-oriented interventions alter the level of PA [24, 35]. It is important to emphasize that a different methodology was also used to evaluate the change in PA in the RCT compared with the present study. In the RCT, the Chronic Pain Acceptance Questionnaire (CPAQ) containing 20 items was used [35]. In the present study, only one statement from the CPAQ was included (“Right now I feel my life is going well, even though I have chronic pain”). However, even though the results are not comparable, they point in the same direction.

Beside physical activity, CBT is a major element in the treatment of CWP [3, 4]. In the present study, the ACT processes were applied to stimulate psychological flexibility and promote self-management. Therefore, questions to stimulate awareness about pain-related thoughts (PFA), feelings (PF), and behavior support (PSM) were included in the diaries (Table 1). The results for these three variables are encouraging, indicating that the psychological condition of participants improved as well as their self-management. Further studies are necessary to replicate these findings.

No correlation between diary contents and feedback messages was found, even though most of the patients stated in their diaries that the feedback was supportive (Table 5). This result suggests that the daily self-monitoring of planned and performed physical activity level, feelings, and thoughts related to avoidance, catastrophizing, and acceptance is helpful to increase self-management, irrespective of the feedback received. Collinge et al. (2013) also suggested that the effects achieved in their study were not dependent on the feedback given. They concluded that by reporting their symptoms electronically, the participants increased their awareness, thereby influencing their behavior positively, leading to a symptom reduction [44]. In contrast, Baumeister et al. (2014) concluded in their review that guided interventions (with feedback), had better results than unguided interventions (self-monitoring), albeit with only slight improvement/effect [45]. Because the feedback messages in the SMI were individualized to the participants' answers, goals, and values, this may have positively influenced the results.

Strengths of the Study

To our knowledge, this is the first study that analyzes the change processes of a smartphone-delivered ACT model intervention by exploring the associations between participants' daily electronic diaries and therapists' daily personal and individualized written feedback messages. The feedback data were collected daily over 4 weeks (excluding weekends). The diary data were collected daily over 5 weeks with several variables collected more than once a day. By analyzing these repeated measures, the intention was to enhance the understanding of the change mechanism in this specific intervention. To analyze the effects of randomized controlled studies, it is a common practice to apply recognized instruments before and after intervention. When instruments are applied at specific time points, the results can be highly biased by a number of factors such as mood, health, and social conditions [46]. By using repeated daily measures, as in the present study, it is possible to evaluate the development of measures over time. Even if these results might be influenced by bias, it is possible to identify trends that should support the main findings and/or provide knowledge for the future development of the intervention.

Limitations

The results of this study should be interpreted with caution because of the complexity in the intervention; that is, the effects may be a result of the treatment program, the SMI, or a combination of these [47]. The effects analyzed are interrelated and were explored in multiple analyses. Moreover, because the analyses of change processes are exploratory, the findings need to be validated by replicating the study in future research with other and larger samples, as well as with other methods for evaluation. For example, this study did not examine whether process measures were related to

outcome measures, which should be a focus in future studies. Although participants' evaluation of the feedback messages was useful for the therapist, for research purposes, the use of a quantitative rating scale would be more appropriate to strengthen the results.

Practical Implications

The data collected in the RCT study from the diaries and feedback messages open up new possibilities of analysis. The main objective of the present study was to understand the change processes of the SMI. Although we knew from the RCT results that the intervention had an effect, it remained unclear which component of the SMI was responsible for this effect. ACT principles underpinned the design of the intervention. The results of the present study suggest that the ACT processes, contained in feedback messages, were not connected with changes in the diary responses. On the other hand, the participants evaluated feedback messages as supportive and the results also suggest that the ACT-based diary content played an important role in the achieved effect, indicating that the entire intervention package generated the effect. The development of feasible interventions with a lower level of complexity, increased efficiency, and decreased costs is needed. Based on our coding scheme developed in a previous study [32], an automatic generation of feedback messages would be possible. Automatic feedback could be generated from a database and combined with individualized feedback if the diaries indicate this to be required. The intervention could then be developed as an application for smartphones, reducing therapist time and costs. Making such an application available as support for clinical practices and/or in maintenance treatments would help in treating people who do not have easy access to health care institutions. The first step would be to develop and test the concept of automation in an RCT intervention.

CONCLUSIONS

No support was found for an association between diary content and feedback based on ACT. However, the results from the present study indicate that the hypothesized mechanism of change in the ACT-based intervention that was seen in the diaries may have contributed to the positive effects achieved. In particular, the processes of committed actions toward own life values may have helped the participants to stay sufficiently active at home. The diary content may also have contributed to increased levels of pain acceptance, self-management, and positive feelings, and to decreased pain fear and avoidance. Although tentative, the results from the present study provide relevant information that will contribute to the further development of smartphone-delivered interventions to enhance treatment of CWP.

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TABLE 6

TABLE 7

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TABLES AND FIGURES

Table 1 Examples of diary content and timing with analyzed variables

Diary content	Variable	MD	RD	ED	Example of statements (S) with it quantity and answers (A) with alternatives
1. Planned physical activity	PLA PMA PHA	x	x		S: Until the next diary, I plan to... A: List of activities to choose from including low, medium and high level activities respectively (1. Horizontal exercise, 2. Relaxing, 3. Stretching, 4. Exercise in slow tempo and 5. Aerobic exercise).
2. Executed physical activity	ELA EMA EHA		x	x	S: Since the last diary I have done... A: List of activities to choose from including low, medium and high level activities respectively (1. Horizontal exercise, 2. Relaxing, 3. Stretching, 4. Exercise in slow tempo and 5. Aerobic exercise).
3. Evaluation physical activity	EPA			x	S: I am ... with today's activity level A: Five-point Likert scale (0. Very satisfied, 1. Satisfied, 2. Neutral, 3. Unsatisfied, 4. Very unsatisfied).
4. Pain catastrophizing	PC		x		S: 1. Right now I worry about whether the pain will end, 2. Right now I feel that there's nothing I can do to reduce the intensity of the pain and 3. Right now it feels like I can't stand the pain anymore. A: Five-point Likert scale (0. Agree completely, 1. Agree, 2. Not sure, 3. Disagree, 4. Disagree completely).
5. Pain acceptance	PA		x		S: Right now I feel my life is going well, even though I have chronic pain A: Five-point Likert scale (0. Agree completely, 1. Agree, 2. Not sure, 3. Disagree, 4. Disagree completely).
6. Pain fear and avoidance	PFA		x		S: 1. Right now I do not dare to move a lot because of the pain, 2. Right now I try to avoid activities that cause pain, 3. Right now I am afraid of the pain and 4. Right now I believe it is dangerous for me to move my body. A: Five-point Likert scale (0. Agree completely, 1. Agree, 2. Not sure, 3. Disagree, 4. Disagree completely).
7. Pain self-management	PSM		x		S: 1. Right now I use what I have learned to help keep my pain under control, 2. Right now I cope well with the pain, 3. Right now I do what I want, even though it causes increased pain or makes the pain reappear, 4. Right now I am using some strategies to help me better deal with my pain problems and 5. Today I was able to do what I wanted and needed despite the pain. A: Five-point Likert scale (0. Agree completely, 1. Agree, 2. Not sure, 3. Disagree, 4. Disagree completely).
8. Positive feelings	PF	x		x	S: Right now I am (1. In a good mood, 2. Grateful, 3. Relaxed, 4. Satisfied and 5. Enthusiastic) A: Five-point Likert scale (0. Agree completely, 1. Agree, 2. Not sure, 3. Disagree, 4. Disagree completely).
9. Feedback evaluation	FE			x	S: The feedback has helped me ... A: List of answers to choose from (1. To stay suitably active, 2. Be aware of my feelings, 3. Stay positive, 4. Be aware of my coping strategies, 5. The feedback was not helpful today, 6. Received no feedback today and 7. Something else)
Total number of items in the different diaries		18	27	24	

MD morning Diary, *RD* random diary, *ED* evening Diary, *PLA* planned low level activity, *PMA* planned medium level activity, *PHA* planned high level activity, *ELA* executed low level activity, *EMA* executed medium level activity, *EHA* executed high level activity, *EPA* evaluation of physical activities, *PC* pain catastrophizing statements, *PA* pain acceptance statement, *PFA* pain fear and avoidance statements, *PSM* pain self-management statements, *PF* positive feelings, *FE* feedback evaluation

Table 2 Sample characteristics at admission to the inpatient rehabilitation center

Characteristic	Smartphone intervention
Age, mean (SD), <i>n</i>	43 (11.12), 48
Marital status	
Married or cohabiting	66.7 % (<i>n</i> = 32)
Divorced	10.4 % (<i>n</i> = 5)
Single	18.8 % (<i>n</i> = 9)
Widow	2.1 % (<i>n</i> = 1)
Unknown	2.1 % (<i>n</i> = 1)
Years of education	
≤ 10 years (elementary)	16.7 % (<i>n</i> = 8)
11–13 years (high school)	22.9 % (<i>n</i> = 11)
> 13 years (college/university)	52.1 % (<i>n</i> = 25)
Unknown	8.3 % (<i>n</i> = 4)
Employment status	
Working/studying	18.8 % (<i>n</i> = 9)
Unemployed	4.2 % (<i>n</i> = 2)
On sick leave	8.3 % (<i>n</i> = 4)
On disability pension	54.2 % (<i>n</i> = 26)
Part time working/studying and part time sick leave	10.4 % (<i>n</i> = 5)
Unknown	4.1 % (<i>n</i> = 2)
Diagnosed with fibromyalgia	85.4 % (<i>n</i> = 41)
Duration of symptoms (years), mean (SD), <i>n</i>	12.66 (9.33) 45
Current VAS ^a rating (past couple of days) mean (SD) <i>n</i>	66.22(17.58) 48

^a VAS visual analog scale, range 0–100

Table 3 Results of analyses of diary content

Diary content	Variable	Intercept (I) Mean (RESID), <i>P</i> value	Time slope (S) Mean (RESID), <i>P</i> value	I and S effects correlation	Residual SD
1. Planned physical activity	PLA	2.75 (1.16), < 0.01	-0.029 (0.044), < 0.01	-0.328	0.87
	PMA	0.44 (0.35), < 0.01	-0.004 (0.012), 0.16	-0.290	0.50
	PHA	0.39 (0.31), < 0.01	-0.009 (0.008), < 0.01	-0.520	0.42
2. Executed physical activity	ELA	2.19 (0.99), < 0.01	-0.029 (0.029), < 0.01	0.007	0.98
	EMA	0.32 (0.28), < 0.01	-0.004 (*), < 0.01	^a	0.41
	EHA	0.31 (0.31), < 0.01	-0.007 (0.007), < 0.01	-0.724	0.38
3. Evaluation of physical activity	EPA	2.58 (0.57), < 0.01	-0.012 (0.016), < 0.01	-0.366	0.82
4. Pain catastrophizing	PC	6.30 (1.08), < 0.01	0.004 (0.029), 0.46	-0.422	0.86
5. Pain acceptance	PA	2.28 (0.72), < 0.01	-0.011 (0.017), 0.01	0.083	1.30
6. Pain fear and avoidance	PFA	6.75 (1.36), < 0.01	-0.019 (0.057), 0.05	-0.384	1.34
7. Pain self-management	PSM	9.04 (1.29), < 0.01	-0.030 (0.039), < 0.01	-0.105	1.53
8. Positive feelings	PF	2.37 (0.69), < 0.01	-0.015 (0.025), < 0.01	-0.393	1.01

SD standard deviation, RESD random effect SD, MD morning diary, RD random diary, ED evening diary, PLA planned low level activity, PMA planned medium level activity, PHA planned high level activity, ELA executed low level activity, EMA executed medium level activity, EHA executed high level activity, EPA evaluation of physical activities, PC pain catastrophizing statements, PA pain acceptance statement, PFA pain fear and avoidance statements, PSM pain self-management statements, PF positive feelings

^a Random effect did not converge and was removed from the model

Table 4 Effect analysis of planned and executed physical activities

Dependent variable	Independent variables	Coefficient estimate	<i>P</i> value	Residual SD
Midday executed low level activity	Morning planned low level activity	0.47	< 0.01	0.592
Evening executed low level activity	Midday planned low level activity	0.27	< 0.01	0.625
Midday executed medium level activity	Morning planned medium level activity	0.34	< 0.01	0.270
Evening executed medium level activity	Midday planned medium level activity	0.31	< 0.01	0.269
Midday executed high level activity	Morning planned high level activity	0.52	< 0.01	0.249
Evening executed high level activity	Midday planned high level activity	0.46	< 0.01	0.224

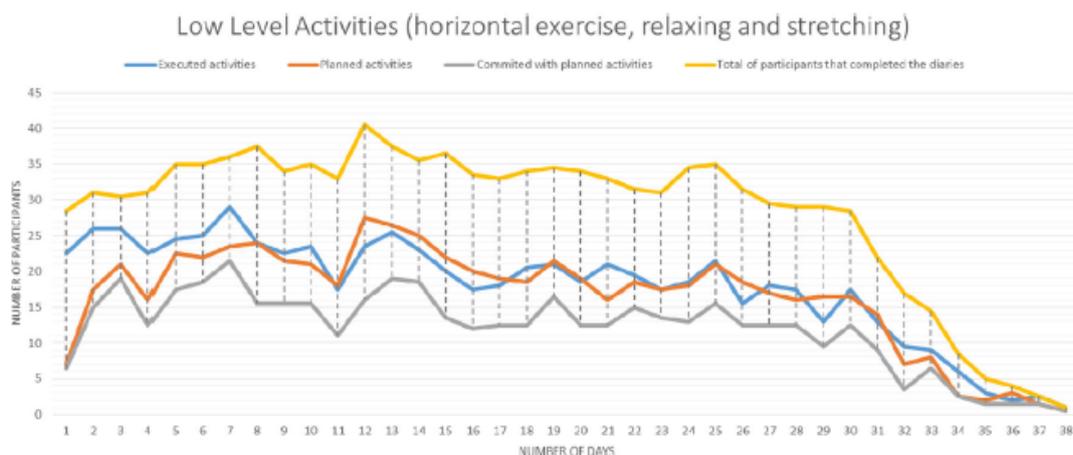


Fig. 1 Mean of low level activities by number of participants that answered the diaries per day. Executed activities = refers to the participants that executed low level activities; Planned activities = refers to participants that planned to execute low level activities; Committed with planned activities = refers to participants that have planned and executed the planned activities

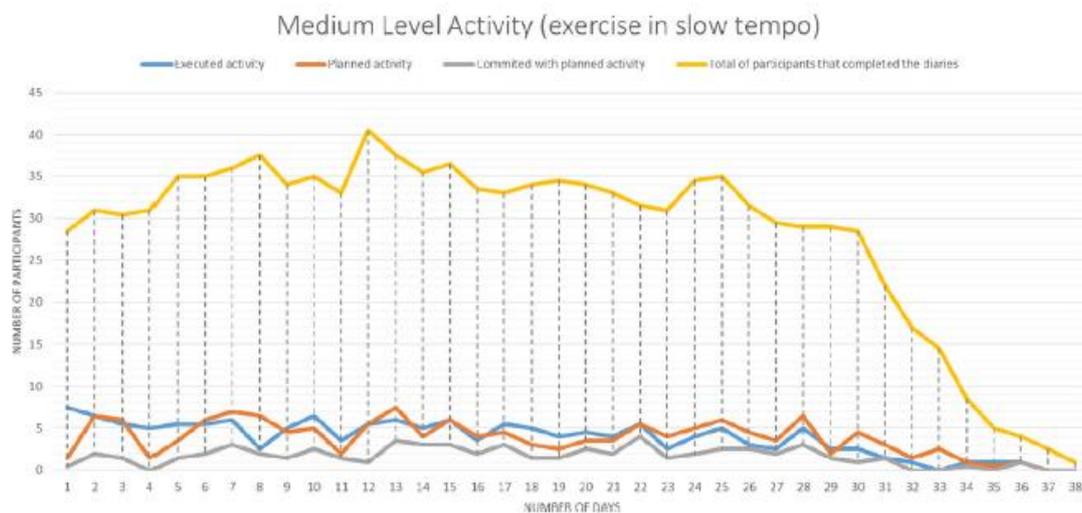


Fig. 2 Mean of medium level activities by number of participants that answered the diaries per day. Legend: Executed activity = refers to the participants that executed medium level activity; Planned activity = refers to participants that planned to execute medium level activity; Committed with planned activity = refers to participants that have planned and executed the planned medium level activity

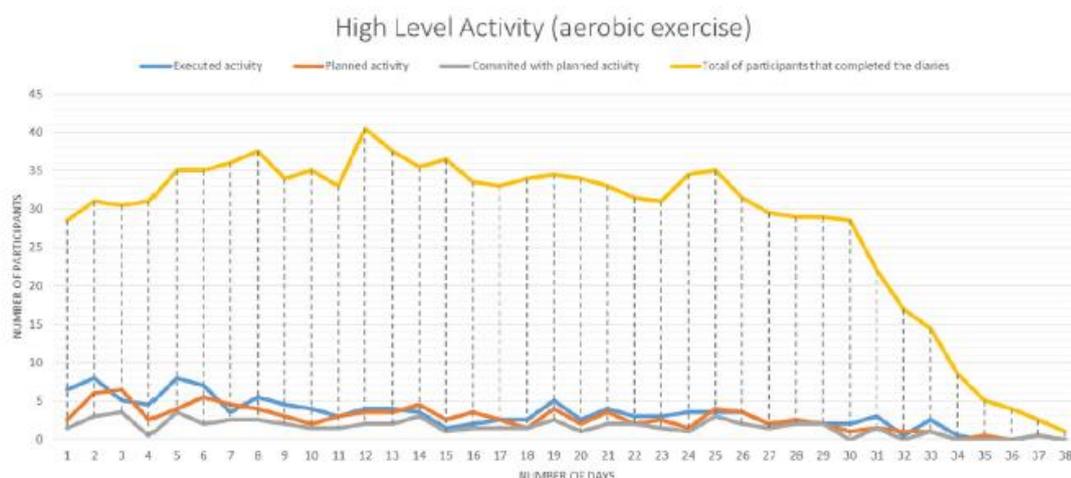


Fig. 3 Mean of high level activities by number of participants that answered the diaries per day. Legend: Executed activity = refers to the participants that executed high level activity; Planned activity = refers to participants that planned to execute high level activity; Committed with planned activity = refers to participants that have planned and executed the planned high level activity

Table 5 Participant's evaluation of feedback messages during 23 days^a

Feedback evaluation	Mean (%)	Std. Deviation	Minimum (n)*	Maximum (n)*
The feedback helped me to stay suitably active	10.00 (26)	6.61	0 (39)	22 (39)
The feedback helped me to be aware of my feelings	8.82 (23)	4.23	1 (39)	15 (39)
The feedback helped me stay positive	6.73 (17)	4.15	0 (39)	14 (39)
The feedback helped to be aware of my coping strategies	2.17 (6)	1.77	0 (39)	6 (39)
The feedback was not helpful today	7.78 (20)	4.28	0 (39)	13 (39)
Completers of the feedback evaluation	24.91 (62)	12.30	1 (40)	39 (40)
Completers of the evening diaries	27.52 (57)	13.41	1 (48)	40 (48)

(n)* maximum number of possible answers

^a The participants did not receive feedback during the first week of the intervention and in the weekends, and these days are therefore not included in the frequencies

Participants' Evaluation of Feedback Messages

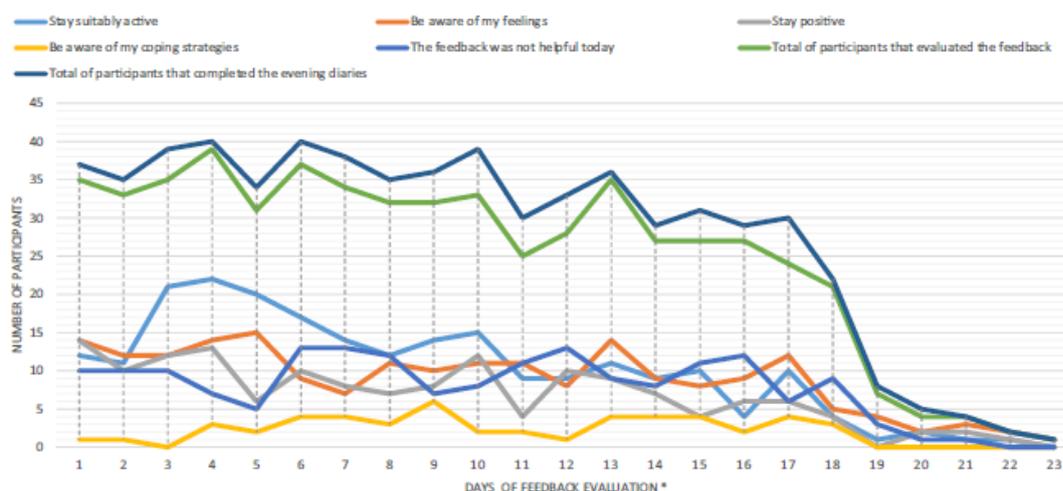


Fig. 4 Evaluation of feedback messages by number of participants that answered the evening diary per day. *The participants did not receive feedback during the first week of the intervention and in the weekends, and these days are therefore not included in the days of feedback evaluation