Does the addition of concurrent visual feedback increase adherence to a home exercise program in people with stroke: a single-case series?

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Research note

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Abstract

Objective Evidence is accumulating for the benefits of technology use in stroke rehabilitation. Few studies have examined ways in which technology can be used to increase adherence to programs after discharge from rehabilitation. The aim of this study was to determine if the addition of concurrent visual feedback, via a tablet computer, increased adherence to an exercise program following stroke. Ten participants were provided with a self-administered exercise program and were asked to perform 60 minutes of exercise daily. After a baseline phase (one week), participants were given a tablet computer (two weeks) and were asked to video record each exercise session. The tablet computer was removed during the fourth week of the program. Results Exercise duration, measured via wrist-worn accelerometry, was investigated over the four weeks using the two-standard deviation (2 SD) band method. A statistically significant effect was observed in four out of ten cases, demonstrated by two successive data points occurring outside the 2 SD band during the intervention phase, suggesting that adherence was increased in response to the tablet computer use. This preliminary study indicates that the use of visual feedback, via a tablet computer, may increase adherence to an exercise program in people with stroke.

Introduction

The use of mobile tablet devices to increase engagement in rehabilitation is increasing as services, staff and clients have greater access to technology [1]. Tablet computers, such as iPads ®, are portable, inexpensive, intuitive to use and many individuals own these devices [2].

Whilst there is an increasing number of mobile applications installed on tablet computers to increase participation in therapy, there is a lack of research around the use of tablet computers as a means of video recording participation in therapy and providing real-time feedback. In a review of tablet use in stroke rehabilitation, Ameer and Ali described the benefits of using a device with a camera within and outside of therapy; including allowing the therapist to record sessions and keep record of patients' performance, as well as providing real-time feedback [3]. This finding is consistent with an exploratory study using video feedback of functional tasks after stroke, which found that participants who were provided with visual feedback during a task expressed more satisfaction with their performance [4]. Currently there is a lack of studies investigating the role real-time feedback, via tablet use, may play in exercise adherence following stroke, and the potential use of these devices as a method to promote exercise adherence should be explored.

Technology devices can also be utilised as a method to monitor adherence. Adherence has been described as 'the extent to which a person's behaviour – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a healthcare provider' [5]. Researchers and clinicians require accurate methods to measure adherence. However, measuring adherence to rehabilitation programs is challenging, and consensus regarding the gold standard is lacking [6, 7]. Accelerometers are relatively new wearable sensors, designed to measure movement in activity counts [8]. The advantage of accelerometer use is that an objective measure of performance can be gained. There is evidence that accelerometers produce reliable and valid metrics of upper limb use [9, 10] and the feasibility of using these devices to monitor exercise adherence should be explored.

The primary aim of this study was to determine if the addition of concurrent visual feedback, via a tablet computer, would increase adherence to an upper limb home exercise program in people with stroke.

A secondary aim was to assess the feasibility of use of upper limb accelerometry as a method of monitoring upper limb activity during a home exercise program in people with stroke.

Methods

Ethical approval for this study was granted by The Southern Adelaide Clinical Human Research Ethics Committee (SAC HREC EC00188). Ten participants were recruited from the Flinders Medical Centre – Rehabilitation and Palliative Division. All participants provided written informed consent. Criteria for inclusion were diagnosis of stroke (>3 months), completion of formal rehabilitation and being able to pick up a small block with the stroke-affected hand. Patients were excluded if they were less than 18 years old, had a Mini-Mental State Examination score (MMSE) of less than 24 out of 30 [11], were non-English speaking (or absence of an English-speaking carer) or had a visual deficit preventing technology use. After participants' eligibility screening and written informed consent, baseline outcome measures were collected to provide an understanding of demographics of the participants. Measures were Fugl-Meyer Assessment (FMA) [12], Modified Rankine Score (0-6) modified [13], Motor Activity Log-14 (MAL-14) [14], Self-Efficacy for Exercise Scale [15], Box and Block Test (BBT) [16], line bisection test [17] and the Technology Use Questionnaire (developed by authors, see Appendix 1). This study adheres to the CONSORT guidelines for clinical trials.

A single-case series design was employed [18] with an A-B-A design. A single-case series design was chosen as it allows for detailed testing of the efficacy of an intervention on a chosen outcome. In single-case experiments, many sequential measurements are recorded for each participant. After an initial baseline period, an intervention is applied and the effect of this intervention relative to the baseline values is investigated. Following the intervention phase, there is a follow-up phase which features withdrawal of the intervention.

Participants in this study were visited at home by the researcher. Following completion of baseline measures the participants were instructed in the Graded Repetitive Arm Supplementary Program (GRASP) [19] and were asked to practice their tailored home program for a total of 60 minutes each day, daily for four weeks. The GRASP program, a self-directed arm and hand exercise program which has been shown to improve arm and hand function after stroke, prescribes one hour of daily upper limb exercises and a manual of exercises is provided [19]. Participants were provided with a recording sheet to record the amount of time spent exercising during each session.

Intervention (tablet computer use)

During the intervention phase (weeks 2 and 3), participants were provided with a tablet computer (Apple model A1474) and were asked to video record each exercise session, using the MoviePro App, a videorecording app that was downloaded onto the tablet computer for a small fee paid by the research project. This required participants to tap on a single mobile application, pressing a Record button at the start and end of each session. The tablet computer was set up in front of the participant so that they were able to see themselves exercising and they were instructed to look at the screen as they exercised. Participants also recorded the start and finish times of each exercise session on a recording sheet provided. This enabled verification of accelerometry data if it was required.

Measurements

Participants were provided with two wrist-worn accelerometers (Actigraph, Pensacola, FL) and were instructed to don these prior to their exercise session and to remove them at the completion of each exercise session. The Actigraph, a lightweight accelerometer that resembles a wristwatch, measures movement of the upper limb through acceleration which is the change in speed with respect to time. Data from two or three axes of movement are combined to provide the output.

The outcome measure used to evaluate adherence in this study was active time when wearing the accelerometer. At the completion of the study the researcher downloaded recordings from the Actigraph devices. Data was analysed using the Actilife Softwear, version 6.13.3 and Actigraph active time was calculated for each exercise session.

To evaluate feasibility of accelerometry use as a method to measure adherence, The System Usability Scale (SUS), a 1 to 5 Likert scale that measures participants experience with using the technology was completed post-intervention [20]. Additionally, the researcher kept a logbook, recording any issues that arose with the technology.

Data Analysis

Changes in amount of activity recorded on the accelerometers from the baseline phase to the "tablet intervention" phase provided an indication of whether adherence to exercise increased in response to the inclusion of the tablet. In addition, any changes in accelerometer recorded activity following removal of the tablet in the follow-up phase provided extra information to inform interpretation of the data.

In accordance with standards related to single case series research where the participant acts as their own control, 5 measures were analysed in the baseline phase and the mean and standard deviation of measures were calculated to account for the level (mean score) and trend (slope) of the 5 measures prior to introduction of the tablet [21]. Active wear time data were then analysed using the two standard deviation (2 SD) band method which has been recommended for the analysis of single-case series designs [18, 22, 23]. If two or more successive data points within the intervention phase fell outside the 2 SD band (i.e. outside the 95% confidence limits), changes from baseline to intervention were considered statistically significant. Rigour of the methodology was enhanced by replication of the design on 10 different occasions with 10 different participants. This method of evaluation enables variability of performance to be factored into the analysis [24].

Results

Table 1 presents the baseline demographics of participants who were involved in the study.

subject	age	MMSE	FMA	MAL14	Self - Efficacy	MRS	BBT (affected)	BBT (un affected)	Time since stroke (months)	Time since rehabilitation (months)
1	64	26	63	7.2	6.4	2	16	29	58	20
2	52	29	62	5.6	10.0	2	65	81	6	4
3	63	28	62	5.6	8.5	3	32	59	13	6
4	65	27	32	5.0	5.9	3	0	57	24	21
5	65	30	62	4.5	7.4	3	19	63	14	9
6	70	29	33	4.7	10.0	2	2	68	7	3
7	21	30	55	4.7	6.1	2	20	32	110	57
8	62	30	64	7.1	7.5	2	45	64	24	.5
9	56	30	65	7.9	9.7	2	48	54	3	1
10	63	30	35	5.1	7.3	3	36	60	5	4
MMSE; Mini-Mental State Examination (0–30)										
FMA; Fugl-Meyer Assessment (0–66)										
MAL14; Motor Activity Log-14 (0–10)										
Self-Efficacy; Self-efficacy for Exercise Scale (0–10)										
MRS; Modified Rankine Score (0–6)										
BBT; Box and Block Test										

Table 1

Subject demographics at baseline

AIM 1: to determine if the addition of concurrent visual feedback, via a tablet computer, will increase adherence to an upper limb home exercise program in people with stroke

Overall, a significant effect was observed in 4 out of the 10 cases (participants 1, 5, 7, 10), as demonstrated by 2 successive data points occurring outside the 2 SD band during the intervention phase, meaning that these participants performed a significantly greater amount of exercise when they were using the tablet computer to provide feedback. These results are represented in Figure 1.

Furthermore, one participant (participant 9) showed a statistically significant reduction in performance at follow-up when the tablet computer was removed (Figure 2). Participant 1 also demonstrated a statistically significant increase in exercise during the follow-up period.

Nine participants reported that they enjoyed the tablet computer and found it beneficial in terms of giving feedback and improving engagement. Participant 1 reported that he did not like the experience of using the tablet computer as he felt like he was being watched, despite this discomfort, he still self-reported a perception that being recorded improved his adherence.

When time since stroke was investigated, the two participants with the longest time since their strokes (participant 1 = 58 months; participant 7 = 110 months), both showed a statistically significant change. Furthermore, when level of motor ability was explored, 4 of the 6 non responders to the tablet intervention (participants 2, 3, 8 and 9) had recorded a relatively high Box and Block Test score.

AIM 2: to assess the feasibility of use of upper limb accelerometry as a method of monitoring upper limb activity

Accelerometry acceptability was measured via the System Usability Scale. The mean score for the System Usability Scale was 96.5 out of 100, indicating a high level of usability.

The accelerometer devices provided objective data representing exercise times. However, there were several problems in terms of data collection. Issues that arose included missing data (participants 4, 9, 10); despite reportedly charging the devices, data were missing during the last three days of exercise in Participants 4 and 9. One device malfunctioned during the final week for Participant 10. Two participants forgot to put devices on and/or off (participants 2 and 5), on one occasion for each participant. A further two participants forgot to charge the accelerometers (participants 1 and 7), and participant 7 had no recorded data after day 15. Two participants were unable to put the device on the non-affected wrist without assistance (participants 4 and 6).

There were no issues with accelerometry utility or data collection in participants 3 and 8.

Discussion

This study demonstrated that using a tablet computer as a tool to promote adherence (via real-time feedback and video recording) to an upper limb home exercise program can be a useful technique for some people with stroke. A significant improvement in the amount of exercise performed was observed in four of the 10 participants who completed the study. Additionally, a further participant showed a statistically significant reduction in performance at follow-up when the tablet computer was removed.

Most participants reported positive feelings towards the approach. These findings are consistent with those reported by Gilmore and Spaulding who found greater satisfaction in participants who received video feedback during a functional task [4]. Furthermore, in a randomised controlled trial investigating adherence to exercise in people with stroke, Emmerson et al [25] compared paper-based home exercises to home exercises filmed on an electronic tablet. Whilst there were no significant between group differences in adherence, the authors stated that a potential benefit could be the accuracy of movement and feedback aspect of the video use and suggested that this may be evaluated in further studies.

There were no technical issues reported with tablet computer use and all participants managed to operate the devices without any assistance or with minimal assistance from a carer. This aligns with other research that describes features of tablet computers, such as wide touch screen platform, that allow for ease of use in people with stroke [3] and qualitative data that reported tablet computers as easy to use, acceptable and engaging [26].

A ceiling effect was observed in those participants who were highly motivated to participate in the prescribed amount of activity from the beginning of the study; meaning there was less ‘room for improvement’ and hence no statistically significant effect was evident during the intervention period. Testing the effect of the tablet computer on the adherence of a less motivated group of participants would be valuable. Four of the participants who did not show a significant change with the intervention were the participants who had recorded a relatively high score on the Box and Block Test. It may be that the visual feedback provided using technology may be more sought out and utilised when a patient has less motor control, and, therefore, provides the greater benefits. The two participants in this study who presented at the longest time since stroke demonstrated a significant change with the intervention. It may be that this technology is most effective when patients are in the chronic phase of recovery, but this needs to be considered with caution.

Most of the participants in this study had enough upper limb movement to enable them to independently don and doff the accelerometers. Two participants, who had a higher level of impairment, required carer assistance to put the devices onto their non-affected wrists.

Some practical issues with utility arose throughout this study. At times participants reported that they forgot to don/doff the accelerometers. Additionally, two participants forgot to charge the devices. Potential interventions to promote reliability of accelerometry use should be considered and may include the use of scheduling applications and phone text reminders. This small study has demonstrated that there are issues that may reduce the utility of home-based accelerometry use in people with stroke. The main advantage of using the accelerometers were that they provided accurate data on exercise time.

Limitations

The study sample was small and could be considered motivated, having consented to a 4-week motor retraining program. This may have influenced adherence to the prescribed activity. A qualitative component to this study would have enabled a greater exploration of participants’ experiences.

Abbreviations

GRASP: Graded Arm Supplementary Program

SUS: System Usability Scale

2 SD: Two standard deviation band method

Declarations

Availability of data and materials

The datasets generated during and/or analysed during this study are available from the corresponding author on request

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Authors contributions

TL and MK conceived the design for the study. TL conducted the research, analysed and interpreted the data and was a major contributor in writing the manuscript. MK assisted in analysis of the data and was a major contributor in writing the manuscript. NL, MC and KL all read and approved the final manuscript.

Ethics approval and consent to participate

Participants gave written informed consent to participate in the study. Ethical approval for this study was granted by The Southern Adelaide Clinical Human Research Ethics Committee (SAC HREC EC00188).

Consent for publications

Not applicable

Competing interests

The authors declare that they have no competing interests

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Figures

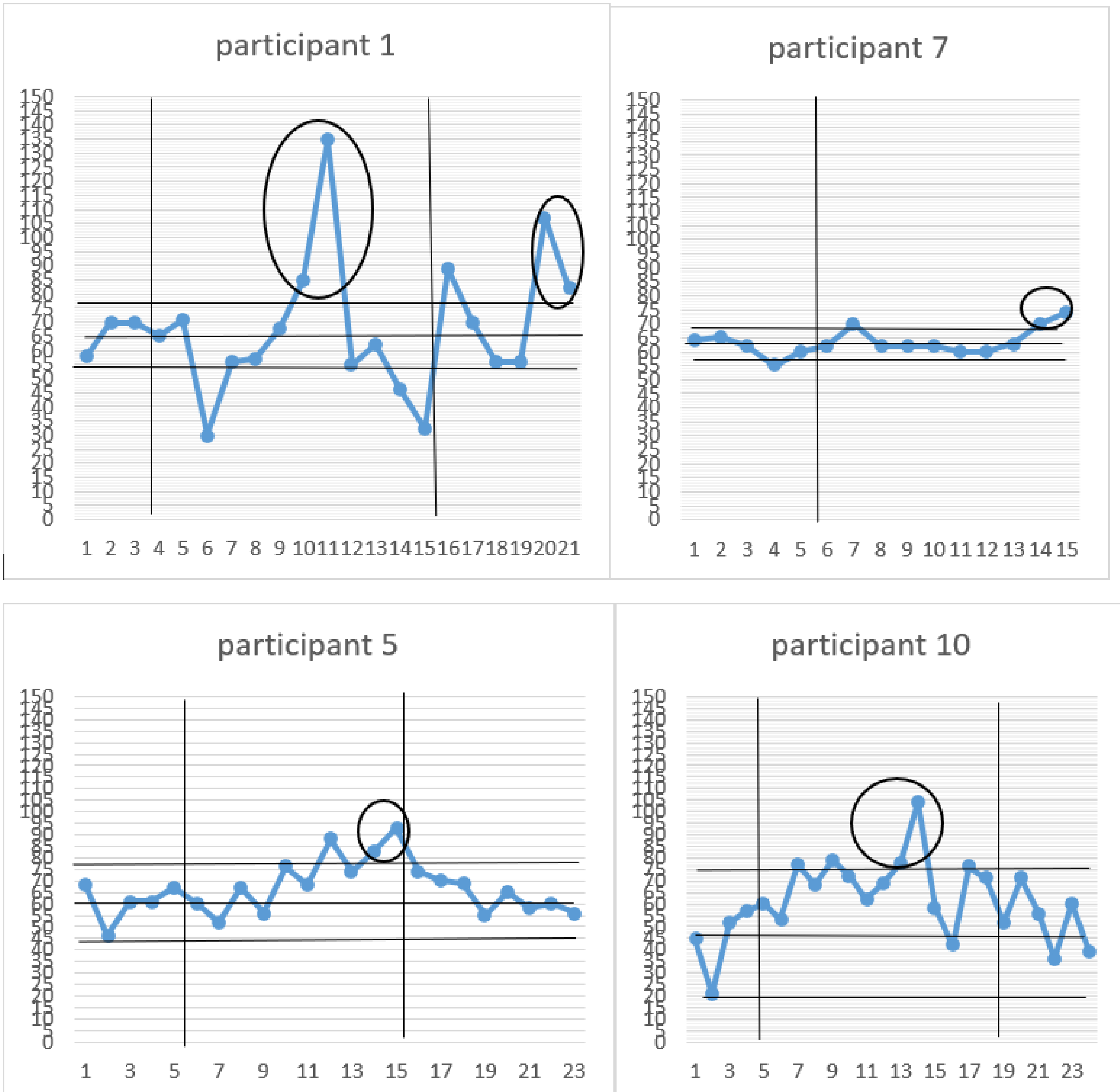

Figure 1

Data points through baseline, intervention and follow-up for Participants 1,5,7 and 10 (significant results circled with 2 consecutive data points outside 2 SD range) X axis represents days of exercise Y axis represents exercise duration (minutes)

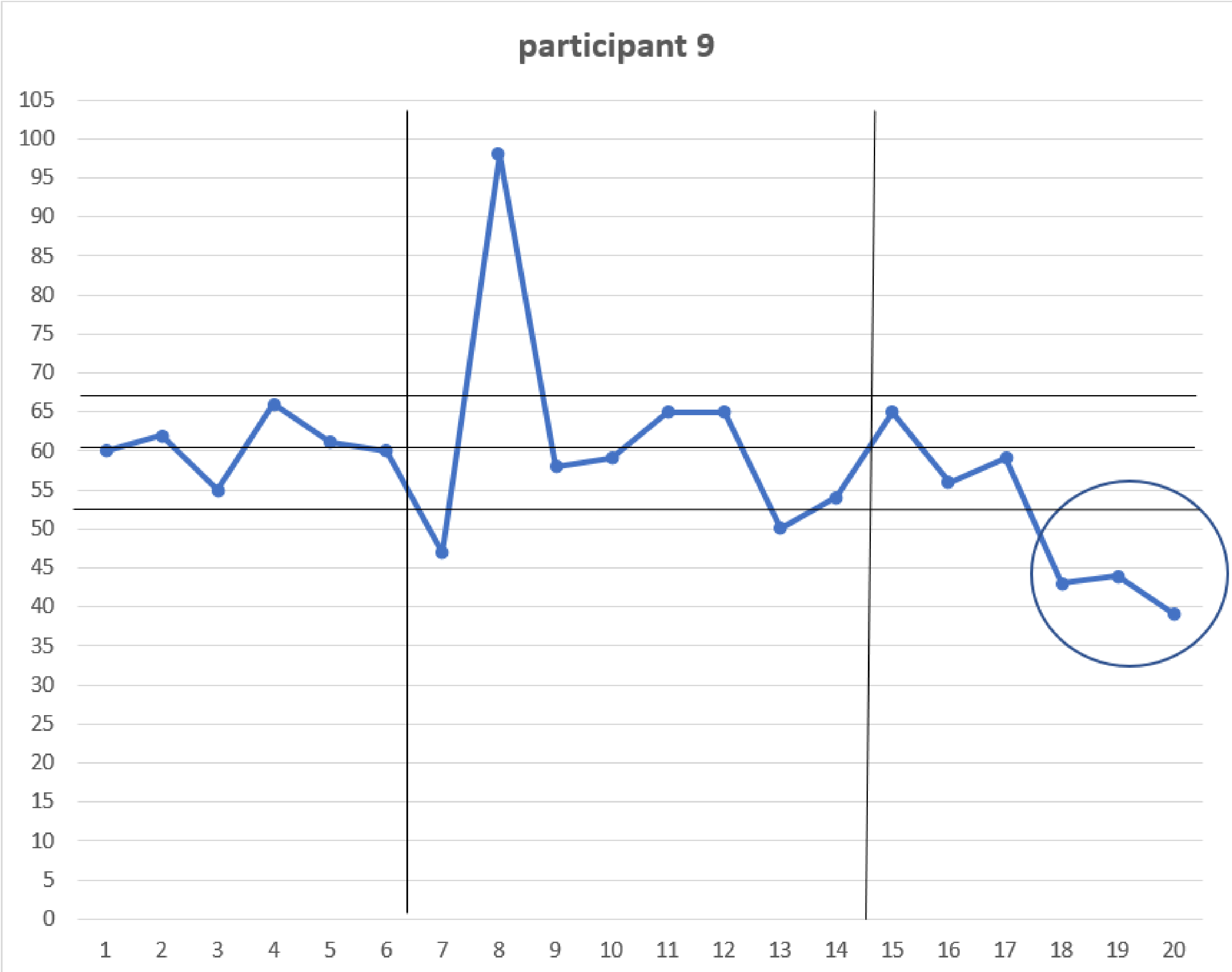

Figure 2

Data points through baseline, intervention and follow-up for Participant 9 (significant result circled with 2 consecutive data points outside 2 SD range) X axis represents days of exercise Y axis represents exercise duration (minutes)

Supplementary Files

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- CONSORT2010Checklist.doc
- Appendix.docx
- responsetable.docx