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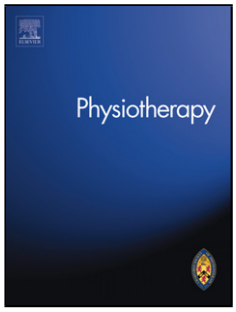

Stroke survivors' recommendations for the visual representation of movement analysis measures: a technical report

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Stroke survivors' recommendations for the visual representation of movement analysis measures: a technical report

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Abstract (210 words)

Background: Stroke survivors do not have routine access to objective feedback on their movement performance

Objective: To devise visual representation of objective measures of movement performance that are understandable by and meaningful to stroke survivors

Design: Co-production through interviews and generative discussion.

Participants: Eight people, mean age 65 years, who were at least one year after stroke with low, medium or high functional ability. All provided informed consent.

Data collection: Participants performed standardised upper and lower limb functional tasks. Their movement was measured using the Vicon motion analysis system and surface electromyography. Participants returned six months later when they were shown anonymised visual representations of the movement tasks. Nobody saw their own data. Visual representations were provided of people with low, medium and high functional ability. A generative discussion elicited participants' views on how the measures should be presented visually to maximise understandability and meaningfulness.

Findings: Participants' understanding of the visual presentation of movement analysis was enhanced with the addition of everyday symbols such as a stick-figure and a brief explanation from a physiotherapist/researcher. Meaningfulness was seen in terms of motivation to participate in and ownership of their rehabilitation.

Implications: These findings justify further development of objective measures of movement performance for use in routine clinical practice.

Keywords: feedback; movement; kinesiology, applied; electromyography; stroke rehabilitation;

Background

Addressing stroke survivors' top ten priorities for better methods of upper and lower limb rehabilitation [1] will require advances in clinical measurement. Currently clinical measures of movement are too general. Physiotherapists rely on visual observation of motor behaviour to inform therapy prescription and provide patient feedback. Such subjective measures of movement provide insufficient information to differentiate recovery from compensation [2–4]. This is important as anticipated advances in clinical rehabilitation will drive beneficial

neuroplasticity to effect true recovery of pre-stroke movement patterns. True recovery of movement requires measurement using motion analysis (kinematics) [5]. Objective measures of muscle activity derived from EMG also provide information to differentiate recovery from compensation. Although kinematic and EMG measures have been used in clinical research for many years, their use in clinical stroke rehabilitation will require simpler methods of data collection and analysis [2].

Movement analysis measures are also important to stroke survivors as they have the potential to provide them with objective feedback on performance and progress. Perceived lack of feedback reduces motivation [6] and causes patient dissatisfaction [7]. As engagement in rehabilitation (saliency, specificity, intensity and repetition [8]) is important for driving beneficial plasticity, objective feedback is helpful. However, physiotherapists report providing feedback based on objective data less than 50% of the time [9]. In contrast, stroke survivors emphasise a need for objective, regular and personalised feedback [7], preferably from an external source [10] to enable them to achieve greater autonomy [11].

The study reported here is an initial step on a pathway towards addressing the challenges of providing kinematic and EMG measures for use in a clinical setting. Working directly with stroke survivors we addressed the following objectives:

1. to collect stroke survivors' perspectives on the experience of undergoing movement analysis measures;
2. to increase understanding of how objective movement measures should be presented so that they are understandable and meaningful to stroke survivors

Methods

Design

Co-production through interviews and generative discussion. All participants provided informed consent before recruitment into the study.

Participants

Ten adults (3 female, 7 male), average age 64.8 (Std Dev 8.4) years who had a stroke between one and twelve years previously. All provided informed consent. Participants were categorised as either low, medium or high functioning for upper and lower limbs depending on their answers to questions about the functional use of their arm and their walking ability (details in online supplement). Thus, the data collected represented a range of functional ability.

Procedure and data collection

After providing informed consent, participants attended the university's movement analysis laboratory (MoveExLab). The Vicon Plug-In Gait model was used (Vicon Motion Systems Ltd, Oxford, UK). In addition, surface Electromyography (sEMG) data were collected using wireless EMG sensors (Trigno^{TM}, Delsys Inc., USA) placed in accordance with the SENIAM guidelines. Each participant was asked to perform a set of standardised, everyday functional tasks. Details of data collection are provided in the online supplement.

Immediately after completing the movement assessment, each participant undertook a short interview with another researcher in a private room. The interview was structured to enable participants to provide their views on the acceptability of the experience of undertaking the movement measures and if any aspect of the process could be improved.

In preparation for participants' second visit to the university, data were processed using Vicon Nexus software and exported to Excel™. Then, graphs of joint angles, movement trajectories and sEMG patterns were produced.

Participants made their second visit to the university five to six months after movement data collection. They met individually or in pairs with the researchers who showed them three graphical, visual, representations of the movement data. All representations were anonymised, and nobody was shown their own results. The representations were of the tasks: sit-to-stand-to-sit, lower limb kinematics; sEMG activity; and the trajectory of wrist, elbow, shoulder and clavicle markers whilst sliding arm through an arc. Each representation showed: someone having difficulty performing the movement; someone finding the task easy; someone in-between the two extremes (Fig. 1a).

Participants were told which task was represented and asked: (a) if they could identify more and less able movements; (b) how understandable the graphs were; and (c) if presentations could be more meaningful. It was emphasised there were no right or wrong answers.

Each generative discussion began with stroke survivors indicating what did or did not seem understandable or meaningful to them. A free-flowing question-and-answer discussion then ensued between participants and researchers to elucidate what was most suitable and understandable in representing the movement results.

The first three participants suggested that "less scientific" and "more everyday" representations would increase their understanding. Consequently, remaining participants

were shown, in addition to the graphs, some everyday objects and symbols (Fig. 1b). They were asked if such representations could add to understandability.

Data analysis

Thematic analysis was employed to analyse participants' perspectives on the experience of undertaking the movement analysis measures (objective 1) and their views on the different visual representations of the measures (objective 2). Notes of the interviews and generative discussions were read iteratively by one researcher to identify main themes and sub-themes. Outlying cases were included. The themes and sub-themes were then discussed with other team members. Consensus was reached, including ordering the themes to reflect commonality and breadth of views.

Findings

Two of the ten participants did not make the second visit. One person had an extended holiday absence and the other had personal commitments that restricted availability.

Experience of undertaking the measurement procedure (objective 1)

Participants described taking part in the movement measures positively: "interesting", "fascinating", "intriguing" (P-004, P-006, P-007 respectively). Some found the sensors or a specific task particularly interesting, while others did not report one part of the experience more interesting than any other. Although most participants stated they would not change anything to improve their experience, a few distinct insights emerged. One participant found the removal of the reflective markers slightly painful; another likened the force-plates to a

"trap door" (S-010) and suggested that participants be told the floor was safe to walk on (details in Table 1).

Understandability and meaningfulness of the visual representations of the measures (objective 2)

Three themes emerged from the participants' views of understandability and meaningfulness of the visual representations of the measures. These are summarised here. Fuller details are provided in Tables 1 and 2.

Theme 1. Providing stroke survivors with greater understanding of their recovery process (table 1)

The initial reaction of seven participants to the graphs was that they were not meaningful and some gave a wrong, or only partially correct, interpretation. By contrast, the eighth participant made an accurate interpretation because of accomplishment in reading graphs.

Participants' understanding of the graphs increased substantially after a brief explanation from the researchers. On learning that changes between a "shaky line" and a more stable line on a graph indicated progress in ankle, knee and hip movements, one participant said this knowledge would have helped his recovery because "it shows improvements in walking" (P-005).

Most participants approved of everyday symbols such as traffic lights and radio signals because they suggested a sense of movement and enabled relating quickly to the significance of the movement measures. Of the everyday objects, the stick-figure was considered useful

by six of the eight participants. No participant felt that these items should replace graphical representations, but rather be used with graphs.

Weighing scales, petrol gauges and footprints in sand, by contrast, were deemed meaningless. Participants expressed caution around objects that might appear juvenile (emoticons), talking down to stroke patients (speedometers; emoticons) or connote inappropriate associations (flasks could be read as specimen bottles). Some participants recommended gender-free and age-free symbols such as the stick-figure. Two participants liked the radio signals, associating the label "strong signal" to "strong movement" (P-004, P-006). In contrast, another participant warned that unless a stroke patient could read, any lengthy words accompanying the image would likely be meaningless.

Theme 2. Stroke survivors' motivation to participate in their rehabilitation (table 2)

Motivation was the common ingredient in successful rehabilitation for all participants, regardless of their initial reaction to the representations. For example, one participant did not find the arm trajectory easier to interpret than the other graphs. However, upon being told what it was showing she responded identically to the others: it would be beneficial in recovery because "you can see the progress" (P-010).. Based on their own experience, participants also projected that "seeing progress" (P-006, P-010) in results would likely provide a meaningful boost to stroke rehabilitation patients, motivating them to continue with exercises.

Understanding and then believing in their own progress was reported by participants as a significant motivator. They envisaged concrete benefits to their rehabilitation by working

with a therapist who showed them their results and explained what the movement measures indicated. Increased understanding had a direct impact on the acceptability and relevance to them of including the graphs in therapy sessions. As one remarked: "I just need the explanation" (P-006). Of key significance was the resultant increase in the sense of purpose to rehabilitation exercises. One participant stated that a therapist making a link between the graph and her recovery would likely inject more purpose to the exercises.

Setting goals was reported by a participant as essential to his motivation during his rehabilitation. He liked "seeing a change [progression] through the graphs" (P-006) because he could set goals for himself.

Theme 3. Involvement and ownership of stroke survivors in their rehabilitation (table 2)

Participants believed that by working in constructive partnership with a therapist who explained what results meant, rather than being recommended an exercise without full context of its purpose, could play an important role in their involvement and sense of control during rehabilitation. Additionally, they believed that the impact on stroke patients' progress would be substantial because it would help them to see their progress in meaningful ways, to identify and understand what needed work and to set goals to move forward in living with their stroke. Furthermore, a sense of moving forward, no matter how small the steps, would engender "positivity" (P-008) within them, which they considered vital to their rehabilitation journey.

Interpretation

This study found that the stroke survivors participating in this investigation had positive experiences of undertaking movement analysis measures (objective 1). Participants' understanding of graphs of the results of movement analysis might be enhanced by brief explanation from a physiotherapist/researcher and the use of everyday symbols such as a stick-figure (objective 2). Participants reported that using visual representations of their movement would be meaningful to them in terms of their motivation to participate in and ownership of their rehabilitation after stroke. These results encourage the further development, through subsequent research, of movement analysis measures that can be used in clinical practice to provide the required distinction between recovery and compensation [1–4]. Furthermore, these results suggest that provision of objective information on movement performance could improve the provision of objective feedback to stroke survivors to provide the required autonomy and motivation to participate in the required repetitive exercise-based rehabilitation programme [6,7,10,11].

An obvious limitation to the generalisability of these findings is that this was an early phase study with a small sample size. However, the participants had a range of severity of functional deficit and the data indicate that all had a positive experience of undertaking the measures and interpreting the visual representations of the results. Consequently, the findings justify continuing to undertake research to develop movement analysis measures for use in everyday clinical practice. This should include further development of the identified symbols for eventual use in clinical practice. So far, symbols have only been identified as potentially useful and have not been applied to demonstrate results of movement analysis measures.

Further development towards clinical movement analysis measures now requires subsequent research investigation within clinical settings with physiotherapists as well as stroke survivors. Clearly access to movement analysis laboratories is impractical. Wearable sensors could be the solution but standardisation of measurement is required [12]. Another challenge is which of the many movement characteristics should be measured. Fortunately, there is evidence to inform what movement deficits should be measured after stroke [13–15]. The next step is to begin investigation of the clinical feasibility of using different forms of visual representation of movement performance for stroke survivors. Only after these preliminary steps are complete will it be possible to test the relative clinical efficacy of different forms of visual representation as a method of feedback of movement performance to stroke survivors. The need for further research is given impetus by these findings that stroke survivors reported positive experiences of undertaking movement measures and that these will enhance their rehabilitation.

Ethical approval

Ethical approval for the study was granted by the Research Ethics Committee of X, University of X (Ref. 2015/2016-89). All participants provided informed consent before recruitment into the study.

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Conflict of interest

The authors have no conflicts of interest.

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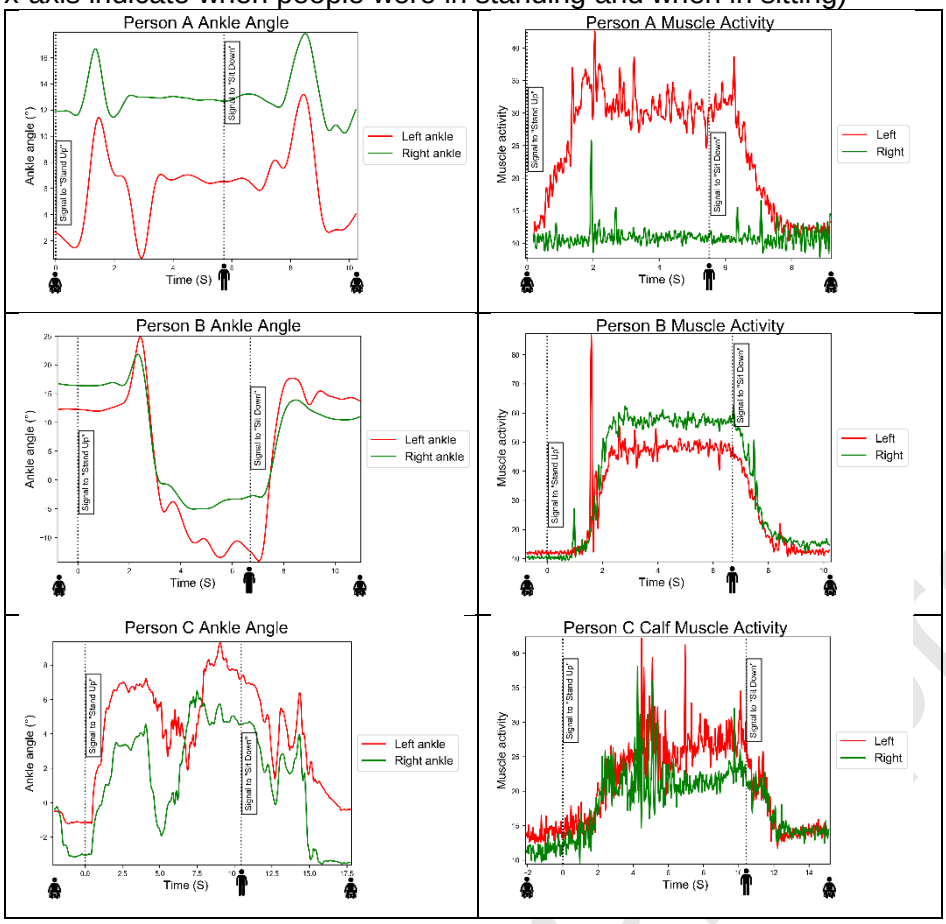
Figure 1. Visual representations of movement measures

1a. Examples of graphs of joint angle and muscle activity shown to participants (icons on the x-axis indicate when people were in standing and when in sitting)



1b. Examples of everyday objects and symbols shown to participants*

*Images are copyright free and accessible from Pixabay.com

Table 1. Experience of taking part in the movement measures

Questions asked of participants	Participants' responses
Can you tell me about your experience of taking part in the movement measures?	It was "interesting"; "fascinating"; "intriguing" (P-004, P-006, P-007 respectively). "The time did not drag" (P-009). "I was interested in doing it. It will help someone." "The movements were similar to what I do in exercise class" (P-004). "I was intrigued with what I was seeing. And I enjoyed it" (P-007). "I like to be involved with anything that could help people who have had a stroke" (P-005).
Was there anything that you found particularly interesting?	"Pedalling! I liked the sense of exercise" (P-001). "Noting where they put the sensors and markers. It was interesting to see" (P-002). "Everything. I was interested in the whole affair" (P-003) "I'll do anything that will improve my stroke status and other people's as well" (P-003). "Pedalling because I don't normally cycle" (P-004). "The reflectors [sensors] – but the whole thing was interesting" (P-007). "How the sensors work; what they actually did" (P-008).
Is there anything that could be changed to improve your experience of taking part?	"There was nothing unpleasant about the experience" (P-004). "More pedalling" (P-001). "Feeling safe is very important; I sometimes wanted my stick when I was standing" (P-001). "Putting on the markers was fiddly; it took a long time but I'm a fairly placid person" (P-004). "Removing the markers was slightly painful" (P-008). "No, I wouldn't change anything. I was expecting it to be harder." (P-007) "Could it be possible to wear a long-sleeve top during the measures?" (P-008) "The force-plates [set into and level with the floor] looked like a trap door. You should reassure future participants that the floor is safe to walk on" (P-010).

Table 2. Stroke survivors' perceptions of the understandability and meaningfulness of visual representations of the movement measures

Themes covered	Participants' views
What provides stroke survivors with greater understanding of their recovery process	"Not meaningful to me" (P-002). "Squiggle indicates pain?" (P-003). "The middle [graph] looks more normal to me; the lines aren't wiggly as in graph A" (P-004). "Having this representation isn't helpful; I'd want [the physio] to explain it to me" (P-004). "Why for A is the green line over the red but B is the reverse? It's confusing." (when explanation given by the research therapist, the participant replied: "I just need the explanation. Now I understand [the graph]") (P-006). "I am used to looking at graphs. These [wobbly lines] suggest the person has problems with stability" (P-010). "The radio signal and the traffic lights, I like that because I can understand straight away" (P-005). "The flasks could be read as specimen bottles and the scales suggest weight to me" (P-010).
Stroke survivors' motivation to participate in their rehabilitation	"A graph showing progress would be for both the physio and the patient. I'd want to see the graph again on visits for rehabilitation" (P-001). "A graph would motivate me, if physio explained it, to participate and continue exercising" (P-004). "And if the graph isn't going the right way, if there's a blip, it gives you an idea of what you need to do to improve again" (P-006). When asked, *would exercises have a purpose, after being shown the graphs?*, one participant replied: "Yes, though it might depend on the stroke. Someone I know didn't understand why she was going to the hospital gym for exercise. I now could tell her" (P-005). "Goals are very important and motivating to me, so seeing a change through the graph – I like it" (P-006). "I'd like a combination of the graph and the radio signal strengths to help me participate [in rehabilitation]" (P-008).
Involvement and ownership of stroke survivors in their rehabilitation	"It's very encouraging to get your head in the right place with something like this, understanding what's happening and you can move yourself forward" (P-008). "…if the graph isn't going the right way, if there's a blip, it gives you an idea of what you need to do to improve again." "Graph #2 makes more sense than the other; it's self-explanatory and I can know what my stroke involves" (P-006). "Having comparisons [with where I'd once been] is therapeutic because I had so much to re-learn" (P-010). "Typically, it's hard for people to think and believe they have improved. With seeing results visually, it really helps" (P-005). "We should keep a record of our journey, based on these results, as a stroke survivor" (P-005). "Use stick-men or traffic lights in exercise plan for those during rehabilitation: see stationary, then get ready, then go. Use this especially instead of long words for people with aphasia" (P-010).