An evaluation of sit-to-stand devices for use in rehabilitation

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1. Introduction

When a patient requires an assistive device to help with the activity of rising from a seat, there are many devices that can deliver the support and movement needed. The functional movement for transport, patient movement or hygiene requirements is common place in healthcare settings. The design and action of most sit-to-stand assistive devices is considered to be active, as the device requires some balance, trunk control and weight-bearing ability in the person being assisted. There is concern that the movement is mostly passive and the support and structure of the device creates and controls all movements in the lower limbs due to fixation at the trunk and knee.

Modern acute healthcare has a clear focus in reducing the length of stay in any setting. Consequently, any advantage that can be gained by encouraging rehabilitation and a faster improvement in ability is welcomed. For a normal, unassisted sit-to-stand, there is a known sequence of actions which are not entirely matched in the assisted actions. This study explores the patterns natural movement against the movements seen in assisted transfers.

In this study, the Sara® Flex was shown to:

- Allow more forward knee movement during rising and lowering
- Allow more bodyweight through the feet during rising
- Give one of the closest **center of pressure** movement patterns to the natural active movement
- Be the was the most preferred device in this trial
- Encourages the participant to be more active through sitting and standing assisted transfers

2. Objectives

The objectives of this study were to explore the relationships between the movement patterns in an unassisted active sit to stand, an active stand to sit, and the movements recorded when using sit-to-stand assistive devices for both tasks. This study compares joint movement, body weight through the feet and the center of pressure through the feet across a number of devices. Subjective evaluations of all devices were also completed to evaluate the user comparison of the devices.

3. Methods

The trial followed a fully squared repeated measures design where all participants (n=20) were exposed to all conditions (n=7, unassisted active plus 6 devices). The order of presentation was balanced to give appropriate comparison. Participants were required to complete three sit to stands and three stand to sits with each device. All data collection methods were piloted with a small number of participants before committing to the full trial.

3.1 Participants

Participants were acquired from local recruitment. All were required to be 55+ years of age and no restrictions were placed on medical history, but each had to be able to complete the sit-to-stand action independently. For all transfers, the participants were requested to raise/lower themselves to the highest/lowest position possible with the device.

3.2 Subjective data collection

After each set of transfers with any device (n=3 repetitions), a range of subjective evaluations were requested from the participant inquiring:

- Comfort during and after transfer
- Security during and after transfer
- Sling fitting
- Quality of the knee support
- Overall performance

All subective evaluations were recorded on 5 point Likert scales (5 being the preferred score). After all devices were completed, a post study interview was conducted. The experimenter recorded verbal comments and the particiant was asked to rate their preference or dislike for various aspects of the devices:

- Overall preference of device
- Preferred slings
- Preferred knee support

3.3 Physical data collection

The movements completed were recorded with three methods: video recordings were taken as a record of each transfer, the ground reaction force was recorded using a six-dimensional force plate, and the limb positions and limb angles were recorded with motion capture (Codamotion with Odin Software).

The data used for analysis was:

- Force measured through force plate
  - Vertical coordinate
- **Center of pressure** location (anterior to posterior, or AP)
- Joint positions from motion capture
  - Foot — Toe, 5th metatarsal and heel
  - Fibula — lateral malleolus and fibula head
  - Femur — Epicondyle and greater trochanter
  - Pelvis — Anterior and posterior iliac spine
  - Shoulder — Acromion
- Joint angles
  - 3D Eular angle calculations were performed by the ODIN software for ankle, knee and hip
- Video recordings were used for clarification

3.4 Conditions

The study compared an unassisted action with the device-assisted transfers. The active movement was self-selected. Participants could use their hands to assist, but this was not included in the analysis. Five comparison devices were purchased (B-F) from the marketplace and adapted to allow for the data collection described above. Device G was a prototype device which had an innovative flexible silicone knee support (Sara Flex). All devices were used in accordance with the manufacturer's instructions for operation and sling fitting. The sling fitting, set-up and controls were controlled by the experimenter.

The conditions were:

A. Active motion, no assistance (control)
B. Knee/shin support, lever lift, sling, flat footplate
C. Knee/shin support, lever lift adjustable, sling, flat footplate
D. Knee support, straight line lift, sling, flat footplate
E. Knee support, lever lift, sling, flat footplate
F. Knee/shin support, lever lift, sling, angled footplate
G. Silicone knee support, lever lift, sling, flat footplate

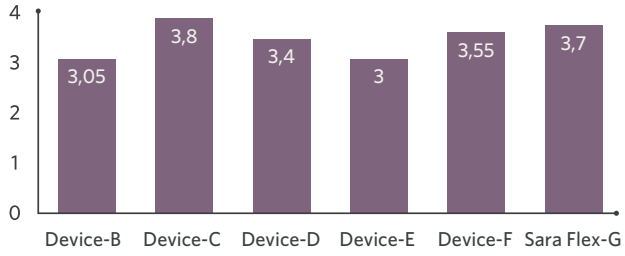
4. Results

Participant characteristics (n = 20) were all over 55 years of age, mass 44.4-109.9 kgs and height 147.3-187.9 cm. Medical histories were recorded, but none were excluded.

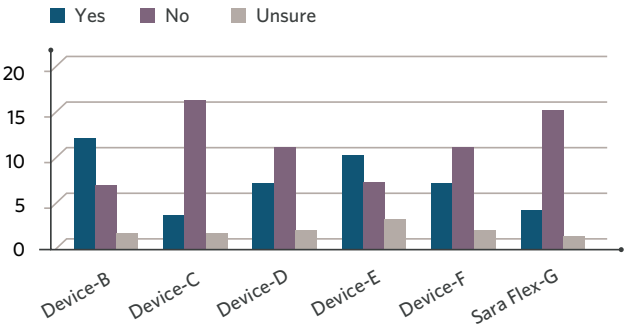
The physical data was filtered for missing data and erroneous data, which was all removed. The movement was identified as starting when the hip marker was raised/lowered 20 mm and finished when the hip marker ceased movement. This gave comparable time frames with only the movement phases being included. To allow comparison between transfers, many data were normalized to percentage figures, e.g. time, weight, center of pressure across the foot length, etc.

4.1 Subjective results

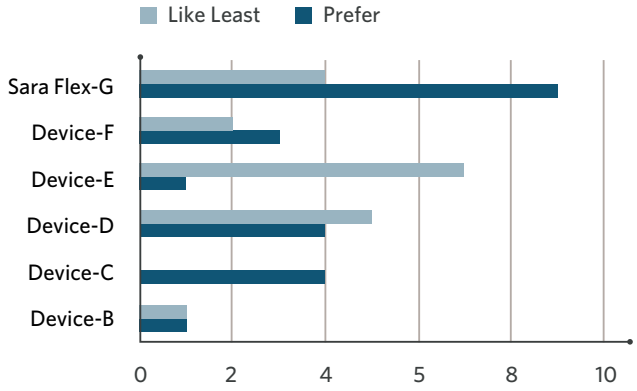
The subjective scores were recorded on 5 point Likert scales. Judgements for raising and lowering were combined, 5 being the positive score and 1 being the least regarded.



Graph 1
Average comfort during the movement
For comfort, the Sara Flex and Device C were the most comfortable.

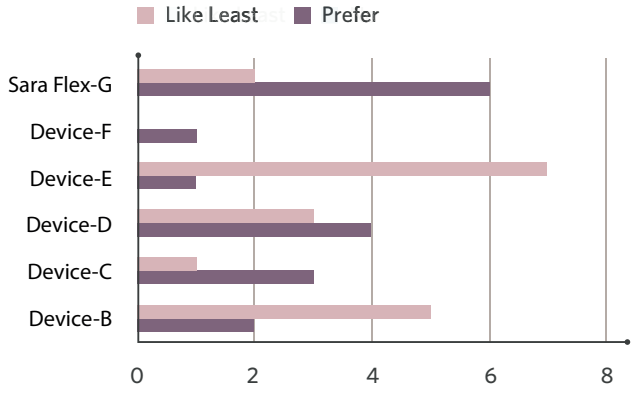


Graph 2
Participants reporting sling movement
The sling movement had a clear relationship with the sensations of comfort and security. Graph 2 showed the frequency that participants reported the sling moving. Devices B, E, D and F reported the most movement, with C and the Sara Flex having the least movement.



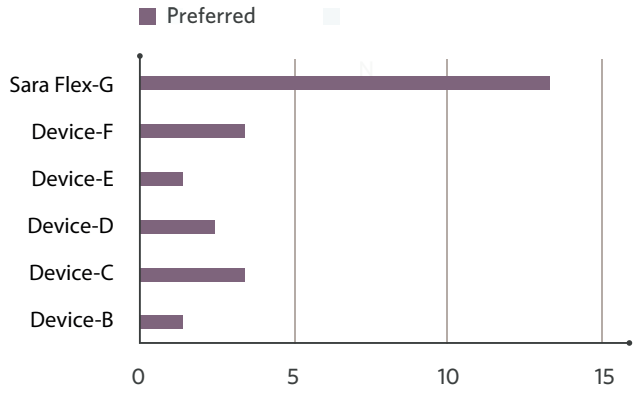
Graph 3
Preference and dislike ratings for devices overall

After the participant had used all devices for all repetitions, the post-trial interview revealed a preference for the Sara Flex device. Participants reported the most preferred and the least preferred across the devices. Graph 3 indicates the most preferred votes for the Sara Flex; however, it should be noted that individual feedback reported that some thought the flexibility felt less secure than others in the range.



Graph 4
Preference and dislike ratings for slings

Graph 4 shows the ratings for the sling preference. Devices B and E recorded more negative views than positive. Specifically E had a slow and very vertical lift pattern which increased the slippage of the sling against the participant. The devices D, C and G had more positive than negative ratings. The Sara Flex device showed the most positive responses. Interestingly, F and G had identical slings, but the combination with the silicone knee support affected the ratings.



Graph 5
Preference for knee supports

While some participants considered the silicone knee support to lack security, Graph 5 shows the overwhelming preference for the Sara Flex knee support during the trial.

Graphs 3, 4 and 5 show Sara Flex to be the most preferred device.

4.2 Subjective summary

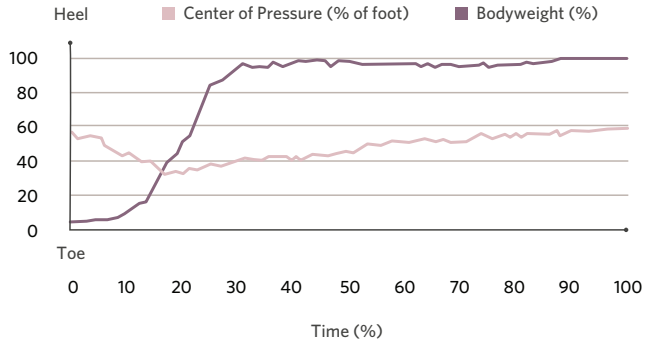
There was a high level of comfort and security with device C and the Sara Flex devices. Both devices were more appreciated by the participants. Specifically, the innovative silicone flexible knee support was the most positive factor in the comfort review. The comparison with natural movement was not possible with the group, as they lacked an insight into rehabilitation requirements.

4.3 Physical results

The first results were used to understand the movement components of the active sit to stand. There was good variation between participants with good correlation between the repetitions for each participant.

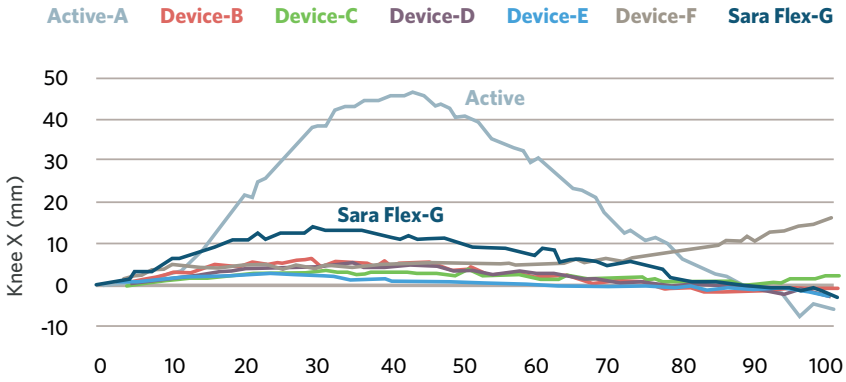
Graph 6
Active sit-to-stand — center of pressure and % bodyweight

Graph 6 shows the % bodyweight (%BW) and the position of the **center of pressure (CoP)**. The CoP plot shows how the weight starts approximately. 60% toward the heel, and as the person stands, the weight moves forward toward the toe and then back again once standing. The %BW is characterized by a rapid onset of force as the weight comes off the seat and there is maximum acceleration up to standing.



The main aim of this study was to explore the relationship between the movement pattern in the active tasks and those reported in the assisted transfers. The analysis of the movement for the active sit-to-stand showed forward movement of the knee with forward lean of the trunk.

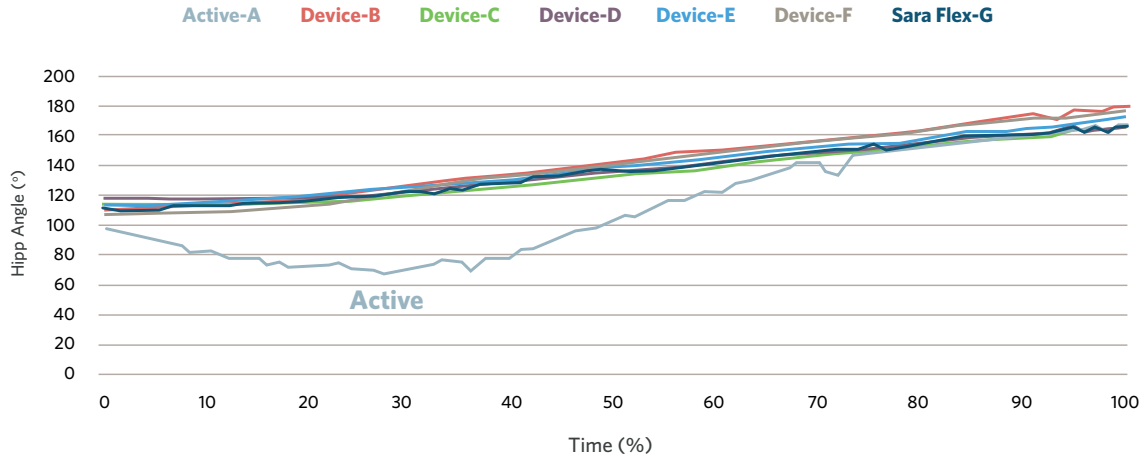
This allowed the weight to be taken on the feet to allow vertical acceleration into standing and a corresponding extension at hip, knee and ankle. The following graphs show some movement comparisons between the devices and the active sit to stand.



Graph 7
Forward knee movement

Graph 7 shows the horizontal movement of the knee as it comes forward over the toes in standing.

The closest device to the active curve is the Sara Flex, which is significantly higher movement than all other devices (P<0.05).

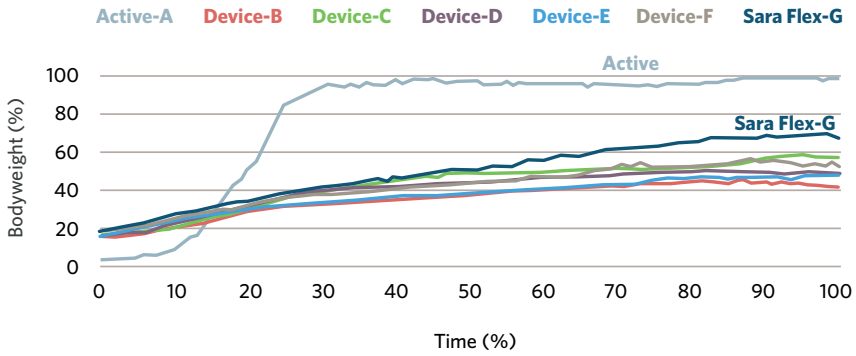


Graph 8
Hip angle during sit to stand

Graph 8 shows the angle between the trunk and the thigh. As the person moves forward, the angle closes and the curve of the median hip angle drops below the assisted movement curves. The backward lean into the sling allows only the steady increase from 90° to upright of approximately 180° for all devices. Similar comparisons were seen in the angles of knee and ankle where movement was seen in the active but much less in the device assisted.

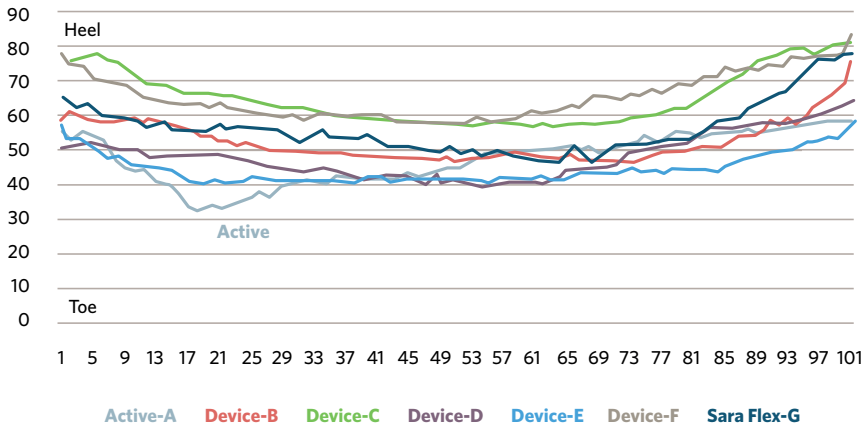
Graph 9
% Bodyweight for the sit-to-stand action

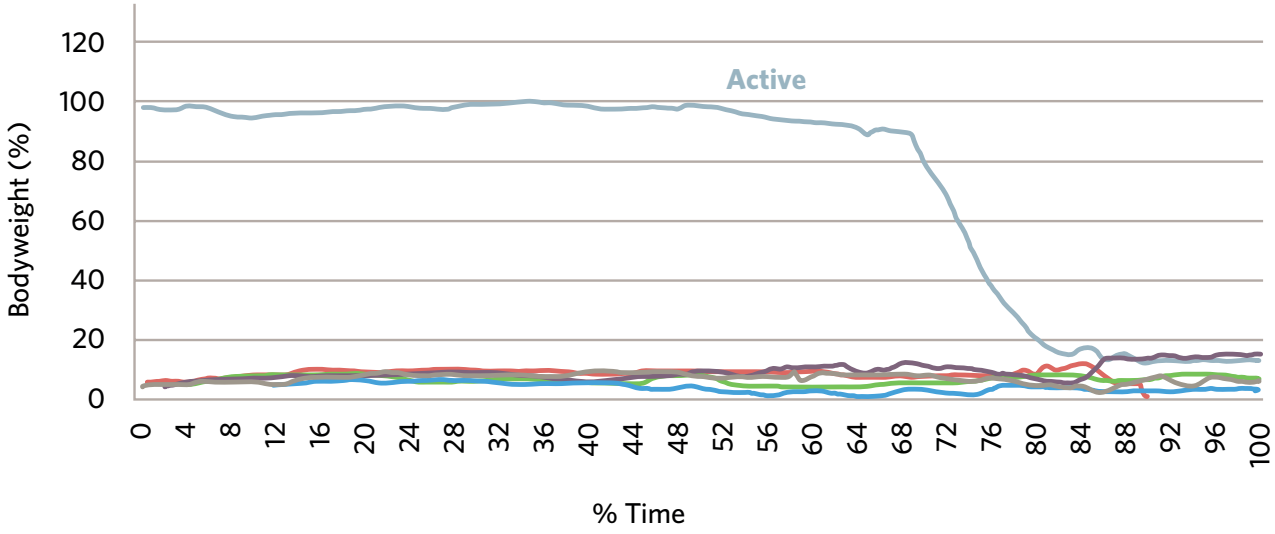
The clearest benefit of the flexible knee support was the effect on the ground reaction force. The Sara Flex allowed up to 70% of the body weight to be measured at the standing position, which was significantly higher than most other devices ($p<0.05$).



Graph 10
% center of pressure for sit to stand

The experimental team expected the CoP for the devices to be much further to the heel as the center of gravity and center of mass is supported by the device outside the base of support. The results show that the CoP movement is much closer to the active pattern than expected. This is explained by the response to being pulled forward by the sling. The participant braced themselves against the footplate and hence, the CoP moved forward toward the toe.





Graph 11
% Bodyweight for stand to sit

In the data that was collected for the stand-to-sit actions, the patterns of movement for horizontal knee movement as well as hip, knee and ankle angles were all very similar and did not follow the active movement pattern. There was, however, a significant change in the bodyweight data. Graph 11 shows that the force being registered at the force plate for the sitting action was very small for all assisted sitting actions.

The Sara Flex had the highest % bodyweight but was still a small percentage.

This dramatic reduction in ground reaction force is a key finding. The video analysis showed that the participants lowered themselves into the knee support and took tension in the sling as per the instruction. This created a physical support between the two fixed positions and made the knee the primary weight bearing structure and not the feet.

4.4 Physical summary

The Sara Flex showed some positive differences to the other devices in this trial and in several data sets, was closest to the active pattern of movement.

This investigation reported:

- When assisted people pushed into the floor and CoP moved toward the toe
- When over-lifted CoP moved toward the toe as weight decreased
- Sara Flex allowed more forward movement at the knee
- Sara Flex allowed more weight through feet compared to other devices
- Sara Flex showed quicker transfer of weight onto feet, like a 'normal' stand
- During lowering (stand-to-sit), very low bodyweight was recorded from all devices

5. Concluding remarks

The distribution of the bodyweight in the different movements is an interesting finding when considering the question of using the devices as an aid to rehabilitation. The Sara Flex allowed more forward knee movement, allowed more bodyweight through the feet and gave one of the closest CoP movement patterns to the active unassisted transfer. With these differences, the Sara Flex was still the most preferred device in this trial. These component actions show that the Sara Flex encourages the participant to be more active through sitting and standing assisted transfers.

Specifically, it should be noted that for an unassisted active stand-to-sit transfer, stronger eccentric muscle activation is required to support lowering. Adding a level of voluntary control in the person's own muscles to support their descent would raise the activity level for people who are assisted. This increase in activity will improve their route to improved function and rehabilitation goals. In our modern healthcare system, this may support earlier access to rehabilitation and lead to an earlier recovery.

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