Using multiple outcome measures to determine skill level in myoelectric prosthesis use

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INTRODUCTION

Most studies on prosthesis usage focus merely on one type of outcome measures, using questionnaires, functional tests, or kinematics. However, a combination of several outcome measures should provide a better picture on prosthesis use (Hill et al. 2009, Lindner et al. 2010, Wright 2009). Using both clinical and more fundamental measures (such as kinematics) would not only provide information about the skill level of a prosthesis user, but would also give insight in the processes from which the level of skill originates. To maximize the insight in the skill level of a prosthesis user the current study gauged a wide range of outcome measures. The aims of this study were 1) to describe prosthetic functioning at different levels of performance; 2) to relate the results of the clinical level to the more fundamental outcome measures; 3) to identify specific parameters in these measures that characterize the level of skill of a user.

METHODS

Six experienced users of a myoelectric forearm prosthesis (mean age 36 years, SD 18 years) volunteered to participate. All participants had a passive wrist rotator.

The Southampton Hand Assessment Procedure (SHAP, Light et al. 2002) was used as a clinical test. SHAP consists of 26 tasks: 12 abstract object tasks—six lightweight and six heavyweight objects—and 14 activities of daily living (ADL) tasks. SHAP evaluates hand functionality and provides an Index of Functionality (a sound hand scores normally between 95 and 100, lower scores reflect decreased hand function). Each task was timed by the participant with help of a timer button.

For the fundamental measures two goal-directed tasks were examined: direct grasping and indirect grasping. Four objects were used in the grasping tasks, three compressible objects, each with a spring of a different resistance, and a solid object. The compressible objects simulated non-rigid objects used in daily life, like a juice carton. All objects were covered with a Velcro strap, which had to be pulled off to simulate manipulation of the object. Movements were recorded with a motion analysis system (Vicon), and a head-mounted eye tracking system (IScan). The participants were instructed to execute each of the tasks as rapidly and as accurately as possible, while trying not to compress the objects.

Because of the individual differences between the participants, the data were analyzed for each participant separately. Time scores of SHAP were transformed to an Index of Functionality score and to z-scores. Mean z-scores were calculated for the lightweight and the heavyweight abstract tasks, and the ADL tasks. The following end point kinematic outcome measures were calculated: reach time, peak velocity of reach, grasp time, plateau time in aperture, termination asynchrony. Compression of the objects was measured to assess grip force control of the prosthetic hand. Two Kruskall-Wallis tests were executed on the dependent variables, and Spearman’s Rho Correlation was determined for the mean z-scores of SHAP and the endpoint kinematics. Joint angles were produced with the Plug-in-Gait model of Vicon and the Range of Motion (ROM) was calculated. Gaze behaviour was scored frame by frame with help of Anvil video-annotation software.

RESULTS

All participants scored far beneath the normal Index of Functionality score of 95-100 with SHAP. There was a large difference between the scores, with a highest score of 71, and a lowest score of 17.

The two different grasp tasks influenced mainly the variables of the transport of the hand towards the object, whereas the effect of objects was mainly reflected in the dependent variables of the grasp and object manipulation. Differences between the participants could clearly be noticed in the dependent variables, reflected in differences in time needed to execute the tasks, and the amount of compression of the objects (see Figure 1).
SHAP scores correlated significantly with reach time, peak velocity, and plateau time.

The movement patterns and the Range of Motion for the direct grasping task and the indirect grasping task were slightly different. Although all participants showed overall the same movement patterns in the joint angles, there was much variation in the amount of shoulder abduction between the participants.

Overall, two types of gaze behaviour were noticed. Four of the participants fixated at the object after the start of the trial, and looked at the object most of the time during the trials. The other two participants looked more at the prosthetic hand during execution of the grasping tasks. No differences of gaze behaviour between the different objects were noticed.

Figure 1: Illustrative example of two participants who performed a direct grasp with a compressible object. The solid line represents the participant who scored the highest on SHAP; the dashed line represents the participant who scored the lowest on SHAP. During the reach of the hand towards the object (A), the hand opened to a maximum aperture, stayed at a plateau for a while, and started to close when the hand was near the object (B). When the object was picked up, two moments of compression could be determined (C). The first compression occurred immediately when the object was picked up (indicated with arrow 1), and the second—farther—compression occurred when the Velcro strip was pulled off (indicated with arrow 2). The difference between the two participants can be clearly noticed in the height of the velocity of the hand during the reach (A), the time needed to execute the task, the length of the plateau in the aperture (B) and the amount of compression of the object (C).

DISCUSSION AND CONCLUSION

By using outcome measures on different levels of description, a good view is provided on the performance of the participants in the various tasks. The results of the different outcome measures were on average in agreement with each other in terms of the level of performance of the participant. The results also supplemented each other as the results of the fundamental outcome measures described in more detail how the participants performed in both the fundamental tasks and the clinical task. The participants that scored higher on the SHAP showed overall better performance in the fundamental outcome measures: they had smaller movement times, more gaze behaviour towards the object than towards the prosthetic hand, and less compression of the objects. This indicates that SHAP has a good discriminative ability for the skill level of the prosthesis user. Moreover, the correlation between SHAP score and the fundamental outcome measures reach time and plateau time in the aperture indicate that these variables are specific discriminative parameters that underlie the level of skill of a prosthesis user. This is very useful in rehabilitation, as one can specifically focus on the discriminative parameters on which an individual scores low. This could enhance the overall skill level of an individual.

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REFERENCES