# A BIOMEDICAL ENGINEERING APPROACH TO SELECT AN APPROPRIATE UPPER LIMB PROSTHESIS

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## ABSTRACT

The loss of a hand or arm is physically and emotionally devastating. The amputees must learn to perform activities of daily living (ADL) and job-related activities with the aid of a prosthesis. Upper limb prostheses are divided into two main control types: body-powered and externally powered. The most common interface for externally-powered prostheses utilizes the electromyogram (EMG) as a signal. This type of device is called myoelectric prosthesis.

The fitting process of an upper-limb prosthetic device onto an amputee is not straight forward. The device has to be well-fit, comfortable, and easy-to-use for the ADL and work. Myoelectric prostheses tend to be the first choice of many but they are not suitable for all type of amputations. Therefore, the objective of this study is to assess whether an amputee should be fitted with a body-powered or myoelectric prosthesis.

The study started with a survey of the local prosthetists to identify the key factors for fitting upper-limb amputees. The factors will be used to develop criteria for favoring either body-powered or myoelectric devices. Then, selected engineering measurements of terminal devices such as grip force and slip can be obtained for body-powered and myoelectric prostheses. Then, a prescription process can be developed by using the criteria with the right type of prosthesis to achieve the amputee's vocational, recreational and psychosocial requirements.

## INTRODUCTION

In 2005, there are approximately 1.6 million amputees in the United States; 8% of these amputees have suffered an upper limb amputation [1]. With the absence of a limb, tasks inherently become more difficult to perform and some are impossible. The use of a prosthetic device provides a means to overcome the restrictions that the lack of a limb implies. However, even with advancements in the field of prosthesis, a prosthetic limb cannot exactly mimic the capabilities of a natural limb.

Upper limb prostheses are divided into two main control types: body-powered and externally powered. A body-powered prosthesis is powered and controlled by gross body movements. There are several ways to control the externally-powered prostheses, but the most common of which is the myoelectric control. The myoelectric prosthesis utilizes the electromyogram (EMG) as a signal. Current prosthetic terminal devices are usually grouped by hands and hooks. For some users, hooks offer excellent functionality. However, hooks are not cosmetically attractive and many amputees will not use them.

The upper limb prosthetic prescription is a rather complex process. Prosthetic prescription for upper limb amputees should be tailored to help meet each patient's functional goals. One should take into consideration comfort, cosmetic, function, reliability, cost [2] and each patient's functional and vocational goals. Frequent uses of the prosthesis and satisfaction with the device's comfort have been shown to significantly improve the prognosis for return to work among persons with limb loss [3].

Each type of prosthesis has its advantages and disadvantages. The prescription of a proper prosthetic device to an amputee may allow the patient to achieve his/her goals for both occupational purposes and daily activities of living. Therefore, the objective of this study is to assess how an amputee should be appropriately fitted with what type of body-powered or myoelectric prosthesis, or both.

## BODY-POWERED VS. MYOELECTRIC PROSTHESES

Body powered prostheses are operated via a harness and cable system to control opening and closing of a terminal device. Body powered control is one of the most popular forms of control because of its simple design, light weight, affordability, and durability [4, 5]. It also provides good sight of the grasped object and can be used in rugged conditions [5]. There are also several disadvantages associated with body-powered prostheses. The most common complaints are the harness discomfort [6-8] and the lack of aesthetic appeal [5].

The other control type of the prostheses is an externally-powered control. Myoelectric prostheses represent the majority of externally-powered prostheses in use nowadays. Myoelectric prostheses rely on the conduction of signals originating from muscle electrical potential called electromyographic (EMG) signals. The major advantages of myoelectric prostheses include appearance, stronger prehension force, freedom from harness, more natural control, and ability to be used in a greater range of function [5, 9-12]. Their major drawbacks are higher cost, greater weight, greater care and maintenance, and less robust [5, 12].

It has also been reported that the working conditions reflect the use of prostheses. Myoelectric prostheses are preferred by amputees where aesthetic is important and who are employed in clean and light work, while body-powered prostheses are used by heavy workers [6].

### Survey

In the present study, an initial survey was conducted. Based on comments collected from professionals involved in prosthetic assessment, the prescription process has both subjective and objective components. Many times, amputees present with high expectations about what prosthesis can achieve without realizing the limitations. The type of work and daily functions can also limit their choices. Therefore, our approach started with a survey which was distributed to a group of local upper-limb prosthetic experts to gather their opinions on key factors for fitting upper-limb prosthetic devices to the amputees. The survey includes questions directly related to the expert experience in terms of prosthesis usage, limitation, exclusion and inclusion factors when prescribing a particular type of prosthesis to an amputee.

### Results

The findings from the survey suggested that the prescription process of prosthetic devices to the amputees depends on several factors include amputees' physical conditions, mental states, goals and expectations. The main advantages of the body-powered prostheses include the lower cost, the lighter weight, and usable in more hostile conditions. Myoelectric prostheses, on the other hand, provide greater grip force, closer to normal physiological control, and wider functional envelope.

Furthermore, when trying to match functional activities that amputees need to perform to the capability of a prosthesis system, the important parameters to consider are range of motion, weight, grip strength and environment. In addition, the survey showed that one of the most important factors for the successful use of upper-limb prostheses is patient's motivation.

## MATCHING CRITERIA FOR PRESCRIPTIVE PROTOCOL

For successful prosthetic prescription, it is very important to select prosthetic components and control schemes by taking into account the vocational and recreational needs and expectations of the amputees. This section proposes some of the matching criteria for prescriptive protocol.

### Prosthetic activities of use

Activities of daily living (ADL):

- eating
- personal care
- dressing.

Job related activities:
- office work
- manual material handling
- vehicle operation
- hand tools operation.

Functional parameters

Based on the functional characterization of selected ADL and job related activities and the survey, the following are the selected functional parameters:

- range of motion (ROM)
- grip strength
- weight
- work condition

Besides the type of control for the prostheses (body-powered or myoelectric), the type of terminal device is also important to consider when selecting the prosthetic components. In order to evaluate the efficiency of the terminal devices, several key functional parameters such as pinch force and slip of different types of terminal devices will be measured under the same condition.

*Pinch force measurements*:

The pinch force of different types of terminal devices (i.e. body-powered hook, myoelectric hand, and Greifer) will be measured by force transducers while each terminal device is used to handle a variety of objects that are used in activities of daily living (ADL) and job-related activities (Figure 1).

Figure 1: Equipment setup for measuring pinch force

*Slip measurements*:

Slip of each terminal device (i.e. body-powered hook, myoelectric hand, and Greifer) will be measured while it is used to handle objects that are made of different types of materials (e.g. wood, plastic, metal). These selected materials are the common types of materials that are used in activities of daily living (ADL) and job-related activities. Continuous force will be applied to the objects. Then, the force when the objects start to slip will be measured.

## EXAMPLE OF MATCHING CRITERIA

1. Each amputee's common prosthetic activities of use will be identified. (Lifting will be used as an example in this case.)
2. Identify functional parameters (i.e. the ROM, weight to be lifted and work condition) that are required for lifting activity.
3. Match the functional parameters for lifting activity to the capabilities of prosthetic devices. The capabilities of prosthetic devices are based on the manufacturer's specifications and the pinch force and slip measurements.
4. Select the type of prosthesis control and terminal device that meet the amputee's functional requirements.

## EXPECTED CONTRIBUTIONS

There is little literature focused on predicting appropriateness prosthetic selection or suggesting relationships between types of prostheses to job specific patient needs. This study will provide the criteria that can be used to develop a prescriptive protocol of upper limb prosthesis to achieve the amputee's vocational, recreational and psychosocial requirements.

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