Estimation of Lower Limb Muscle Strength through the Daniels Scale

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ABSTRACT

1 Introduction

In the healthcare field, particularly in rehabilitation, the Daniels Scale is a commonly used technique to assess muscle strength. Developed by Daniels and Worthingham, this scale classifies muscle strength on a scale from 0 to 5, where each level represents the muscle's ability to move a limb against resistance, as detailed in Table 1. Usa et al. developed a formula to predict maximum muscle strength in young adults, middle-aged, and elderly individuals, based on the theoretical grade 3 strength value of the Scale. They found a linear correlation between this value and maximum strength in young adults, although accuracy decreased in older individuals, particularly in knee flexion [1]. Yepes et al. also combined the Daniels Scale with surface electromyography (sEMG) signals and machine learning algorithms to classify muscle strength in hand grip exercises. Their approach achieved a 68% accuracy across subjects and 71% within subjects, although factors like temperature affected the accuracy of the results [2]. Other applications include the work of Cotri-Melecez et al., where they developed a computer-assisted system to automate the prescription of rehabilitation therapies in patients with ankle fractures. They used the Daniels Scale to assess muscle strength and classify patients, allowing them to determine the type of exercises needed, such as isometric or isotonic. The system, validated with clinical records, achieved an accuracy of 97.4%, proving to be a reliable tool for optimizing clinical decision-making in rehabilitation [3]. Similarly, Hinojosa-Rodríguez et al. investigated the long-term effects of Katona therapy in children with moderate to severe perinatal brain injury, using the Daniels Scale to measure muscle strength. The results showed that 67% of the children treated with early intervention achieved motor performance comparable to a healthy group, highlighting the importance of early intervention in mitigating motor disabilities [4].

This project is based on the previous work of Avellaneda Arroyo et al. [5], who continued the project by Medina Anzaldo, I.B. et al., developing a knee brace equipped with EMG, artificial vision, and a mechatronic system to evaluate the range of motion and muscle strength of the knee. Unlike the traditional Daniels Scale, which is based on qualitative evaluations, this system aims to provide a quantitative measurement of muscle function [6].

The aim of this project is to redesign and optimize the original prototype, introducing improvements in hardware and software, as well as refining the method of muscle strength quantification, thus offering a more efficient and precise tool for healthcare professionals. In the evaluation of Daniels Scale levels, a specific protocol is implemented through lower limb extension exercises to determine each level. The table below shows the Daniels Scale levels for assessing muscle strength, along with the methods used to measure each level.

Table 1: Daniels Scale and its Evaluation Methods

Daniels Scale Level	*Description*	*Proposed Evaluation Method [5]*
Level 0	Total absence of muscle contraction.	EMG signals are used to deny or confirm muscle contraction.
Level 1	Minimal contraction without joint movement.	
Level 2	Active movement without the influence of gravity.	The subject's limb moves in the absence of gravity.
Level 3	Complete active movement against gravity, without additional resistance.	The subject performs full movement against gravity without applying external resistance.
Level 4	Full movement against light or moderate external resistance.	A resistance test is performed with a light torque applied.
Level 5	Total muscle strength, able to resist maximum force.	A resistance test is performed with a large torque applied.

The project's hypothesis is that, by using the torque generated by an actuator, in this case, the AK80-6 motor, it is possible to simulate the resistance corresponding to levels 4 and 5, allowing the accurate determination of the patient's level on the Daniels Scale. Additionally, the force (F) exerted by the patient can be calculated using the formula.

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$$\boldsymbol{F} = \frac{\boldsymbol{T}}{\boldsymbol{r}}, \tag{1}$$

where T is the torque and r is the distance where the resistance is applied (20 cm, equivalent to mid-calf).

2 Design

As shown in Figure 1a, the knee brace will be placed on the lower limb. The aluminum design, adapted to perform the measurement function, will be attached to the knee brace for accurate measurement as shown in Figure 1b.

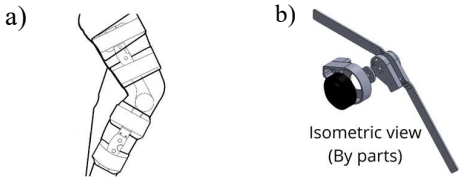

Figure 1: a) Knee Brace; b) Proposed devise redesign

The proposed model is an instrumented knee brace that integrates an AK80-6 motor, using parts manufactured from 6061 aluminum. The link placed over the thigh supports and secures the motor in a stable position, while the rotor connects to the calf link, which is the mobile part of the system, through an aluminum coupling and an adapter specifically designed for this function. Additionally, the axis of rotation of the knee joint is aligned with the axis of the motor's rotor, limiting the movement solely to flexion and extension of the joint.

3 Expected Results

The system is expected to help the medical practitioner to evaluate muscle function using the Daniels Scale, as detailed in Table 1. Additionally, the system should display the force associated with each level of the scale, providing accurate quantitative data. These results will be visualized through a digital interface, where each subject's data can be stored, facilitating medical follow-up and the evaluation of their continuous progress throughout the treatment.

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