EXOSKELETONS AND ASSISTIVE DEVICES FOR HANDS AND WRISTS: A SCOPING REVIEW

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1. INTRODUCTION

Muscle weakness and impairment in the hands and wrist can result from a variety of conditions, which differ in terms of their permanence, severity, and treatment.

In the UK, individuals experience hand impairment due to different factors, including **stroke** (affecting 100,000 people annually [1]), **spinal cord injury** leading to paralysis (2,500 individuals each year [2]), **multiple sclerosis** (impacting 100,000 people [1]) and **Parkinson's disease** (affecting 137,000 people [1]). Furthermore, the natural **aging** process can have an impact leading to reduced muscle strength for pinching and gripping, deterioration of hand function, and diminished prehension [3].

Upper limb function is critical for activities of daily living. Impairment **reduces functional task** performance. These impairments also affect psychological and social difficulties as independence and **quality of life is reduced**.

Exoskeletons and assistive devices provide **additional strength and functionality**. Assistive devices also reduce pressure on the healthcare sector. Yet many commercialised exoskeletons are not designed for hand and wrist support.

2. METHODS

The scoping review was conducted in accordance with the **PRISMA-ScR guidelines** [4]. Search terms were defined using the **PICO framework** [5] and the results will follow a similar structure.

Using the PICO framework, the **patient problem** was generalised as hand and/or wrist impairment, the intervention was the device, comparison was not required, and **the outcome** was defined as outcome measures and results within the study. The **key terms** for the database search therefore included hand, wrist, upper limb, exoskeleton, actuated device, powered device, and assistive device.

The **screening protocol** expected devices to be **wearable** (portable or grounded to mobile structure such as a wheelchair), support **activities of daily living**, and written in English. The data screening and data extraction was completed on Microsoft Excel. Data screening was conducted by two researchers with an agreement level **(accuracy) of 87%.**

The **data charting** components extracted include Title, Author, Year of Publishment, Country of Study, Study Methodology, Participants Information, Target Population, Device Name, Weight of Device (g), Dof (Degree of Freedom), Mechanical Transmission, User Intent, and Outcome Measures [6].

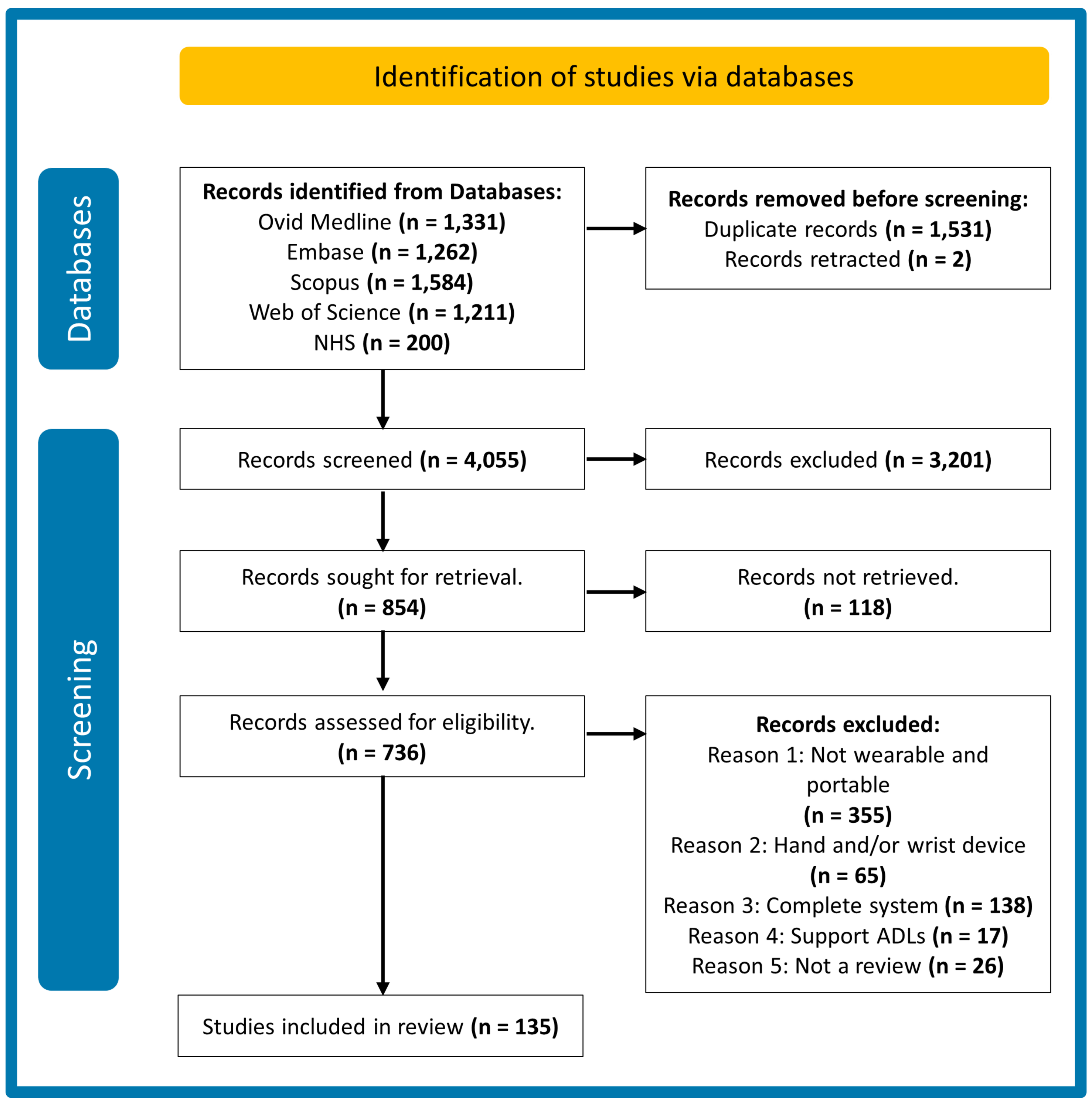

Figure 1: PRISMA Flowchart of database search conducted May 2023

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3. RESULTS

3.1 Demographics:

The PRIMSA flowchart seen in Figure 1, shows **135 studies** were charted, involving **1301 participants [6]**. The database can be found on reference 6.

A total of **30 countries** contributed to the data charting. Correlation (r) between number of studies published per country and sum of participants is 0.867, this strong correlation (r < 0.7) is seen in Figure 2. An outlier to this is Russia, with one publication involving 96 participants.

The oldest publishment found was from 1995 and since then a rapid growth in publications has been seen within the **last 5 years** contributing to almost 50% (64 studies).

The clinical to non-clinical study ratio was 4:6, with experimental methodology being the most popular. Randomised control trials were the most used clinical methodology.

The main **target population** is shown in Figure 3.

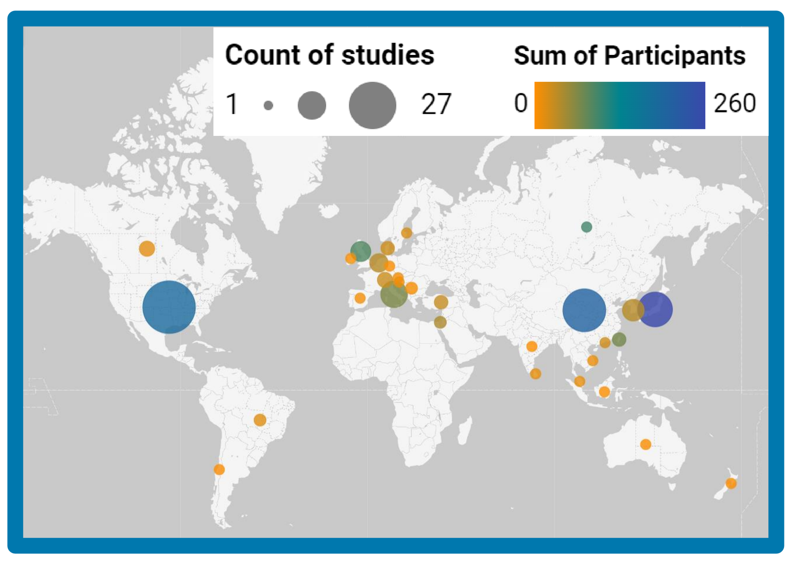

Figure 2: Bubble map of studies and participants in scale

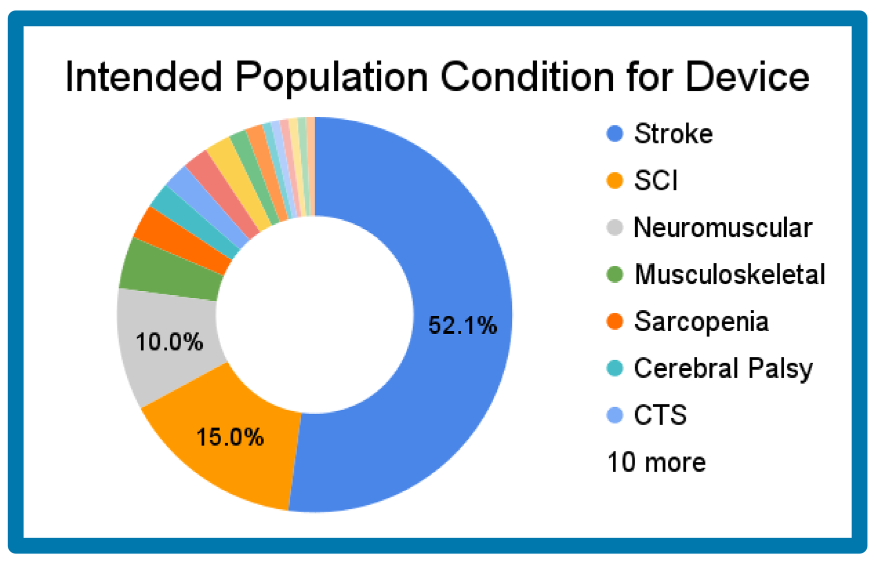

Figure 3: Chart of intended target population

3.2 Intervention:

Mechanical transmission was grouped into 5 main methods represented in Figure 4. **Pulley systems** were the least popular, whereas **direct transmission** was most popular followed by **muscle contraction**.

Muscle contraction is induced during **functional electrical stimulation** and is the main actuation design within clinical studies. **Trends** in mechanical transmission is in Figure 4.

User intent was defined as the **user input for controlling** the device. The user intent varied in the studies. Notable results show that muscle activation recorded using **EMG** is popular, alongside **joint angle and torque**. **Tongue interfaces** are a recent method with high variability between studies in both outcome and control system. Devices which required **manual selection** of actuation often stated future work into more **intuitive** user intent methods.

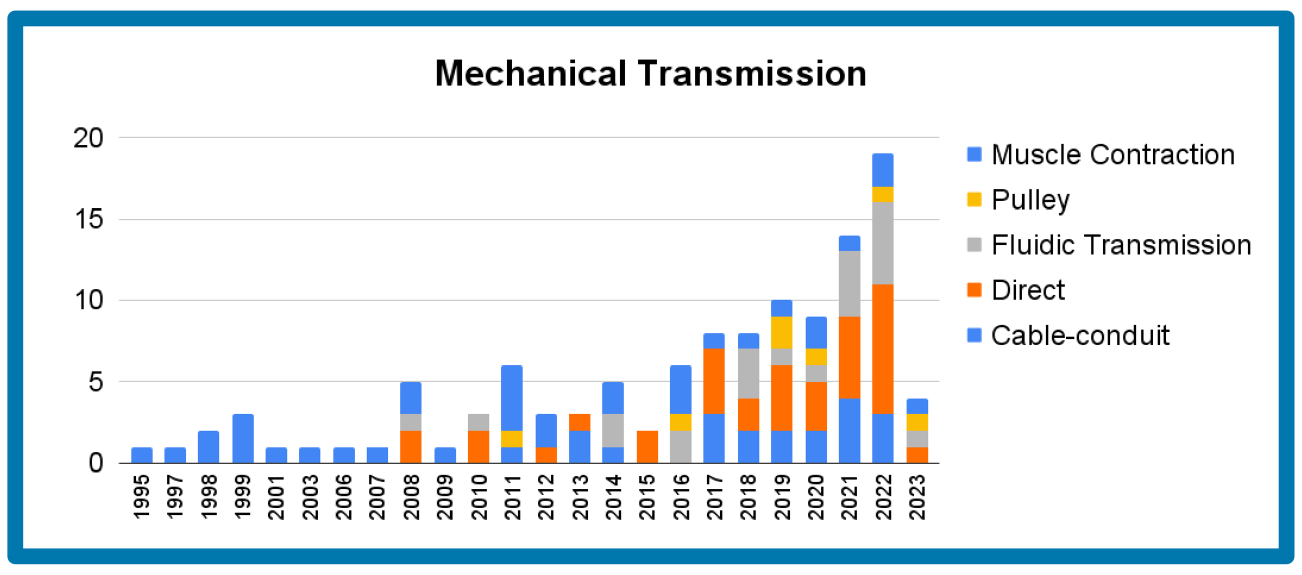

Figure 4: Bar chart trends in Mechanical Transmission

3.4 Outcomes:

228 unique outcome measures were extracted. The most used clinical outcomes were the Ashworth Score, the Fugl-Meyer Assessment (FMA), Range of Motion (**ROM**), Electromyography (**EMG**) and Action Research Art Test (ARAT).

The most used mechanical outcomes were **ROM**, Joint angle, **EMG**, Grasp and Force. Overlap in outcome measures in clinical trials and mechanical test studies was found in outcomes which required **minimal setting up**, and patient recorded outcomes were often unused.

4. CONCLUSIONS

In this scoping review, we identified **135 primary studies** between 1995 and 2023. The findings show diversity in mechanical design, outcome measures, and user intent. Studies cited a lack of a **high-level control systems** as a limitation for designing **low cognitive load** devices. This was prevalent in studies which used manual selection as that is the least intuitive method. Using **EMG** was regarded as a solution to integrate active user intent, but this method is **not inclusive** of target populations which lack **voluntary muscle contraction**, such as stroke affected persons with spasticity in the hands. Efforts should be invested in **assessing clinical outcome measures** and **reducing cognitive load.**

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