ACTIVE AND ACTUATED ASSISTIVE DEVICES FOR THE HANDS AND WRISTS: A 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, such as **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 cause muscle loss, of which, leads to reduced muscle strength for pinching and gripping, deterioration of hand function, and diminished prehension [3].

2. METHODS

The scoping review was conducted in accordance with the **PRISMA-ScR guidelines** [4]. Search terms were defined using the **PCC** (Population /Concept/Context) framework.

Population was hand and/or wrist impairment, the **concept**/intervention was an actuated device, and **context** was defined as during activities of daily living and outcome measures.

Inclusions, exclusions, and screening process are provided in Figure 1. 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** [5].

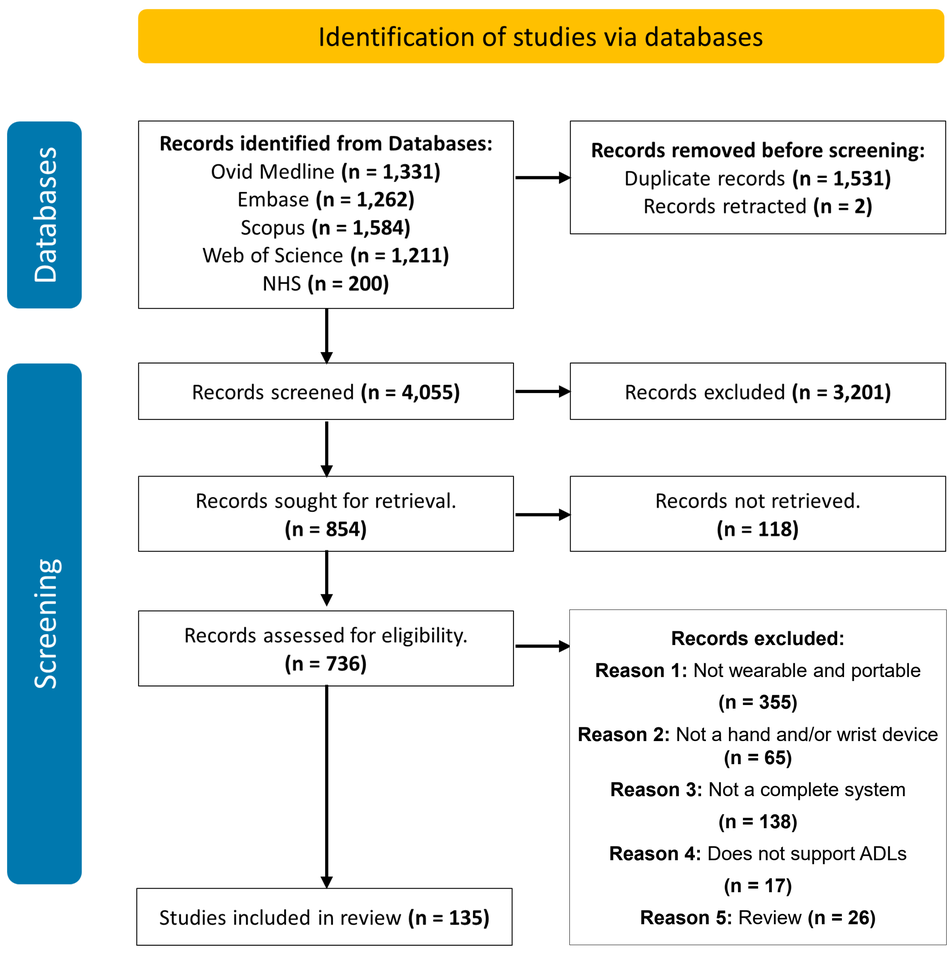


Figure 1: PRISMA Flowchart of database search conducted May 2023

3. RESULTS

3.1 Study Geographics and Methods:

135 studies were charted (Figure 1) from 5,588 identified, involving **1301 participants** [5].

30 countries contributed to the data charting (Figure 2), focused within High to Medium Resource Countries. Correlation (r) between number of studies published per country and sum of participants is **0.867**, this strong correlation ($r < 0.7$) is noticed in Figure 2. The oldest publishment found was from **1995** (Figure 3) 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 (robotic) study ratio (Figure 3) was **4:6**, with experiments being the most popular. **Randomised control trials** were the most used clinical methodology (18 studies).

Figure 2: Bubble map of studies and participants

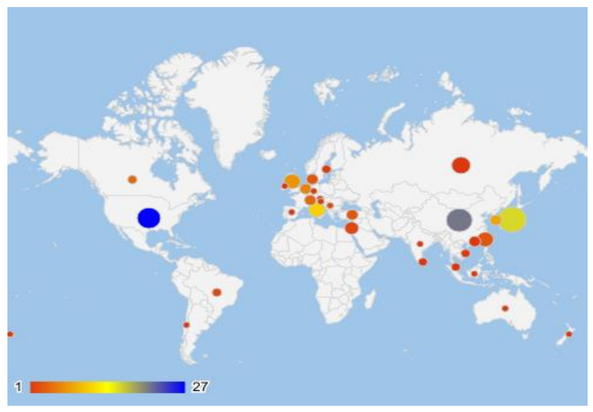
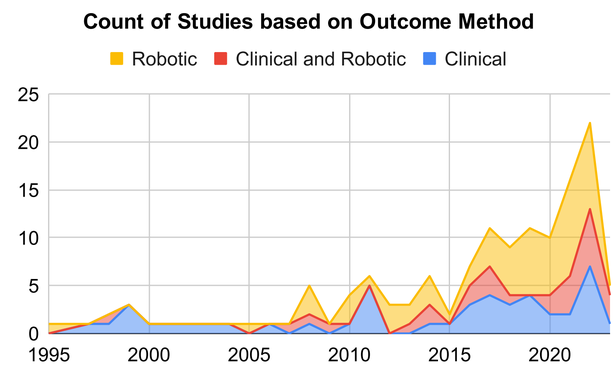


Figure 3: Trends in Publishments



3.2 Intervention and Demographics:

Pulley systems were the least popular actuation method, whereas **direct transmission** (Bar linkage, Direct and Gears) was most used followed by **muscle contraction via stimulation** (Figure 4) which is most used in **clinical studies**. An even distribution of hand and/or wrist device design was noted with limited correlation to design or intended patient population.

The distribution of intended population in Figure 5 **does not mirror the proportions** of those patient populations in our current world. For example, **musculoskeletal injury** intended devices was 4.3%, but affects **2.41 billion individuals** that would benefit from rehabilitation [6] compared to stroke intended devices which was 52.1% but affects **143 million DALYs** [7].

Figure 4: Bar chart of Mechanical Transmission

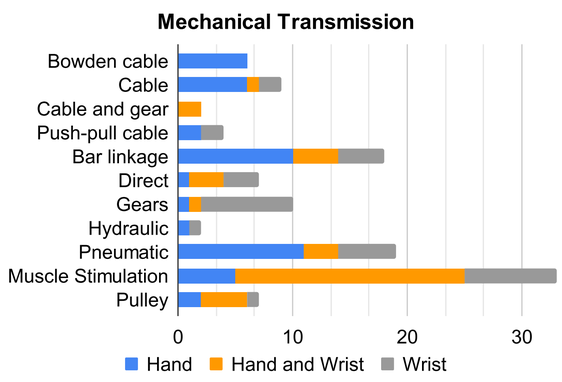
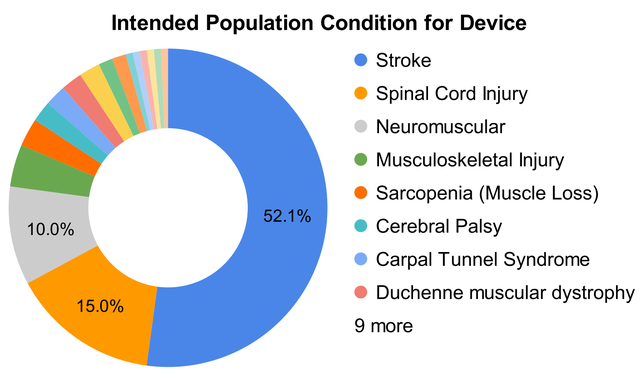


Figure 5: Chart of intended target population



3.4 Outcomes:

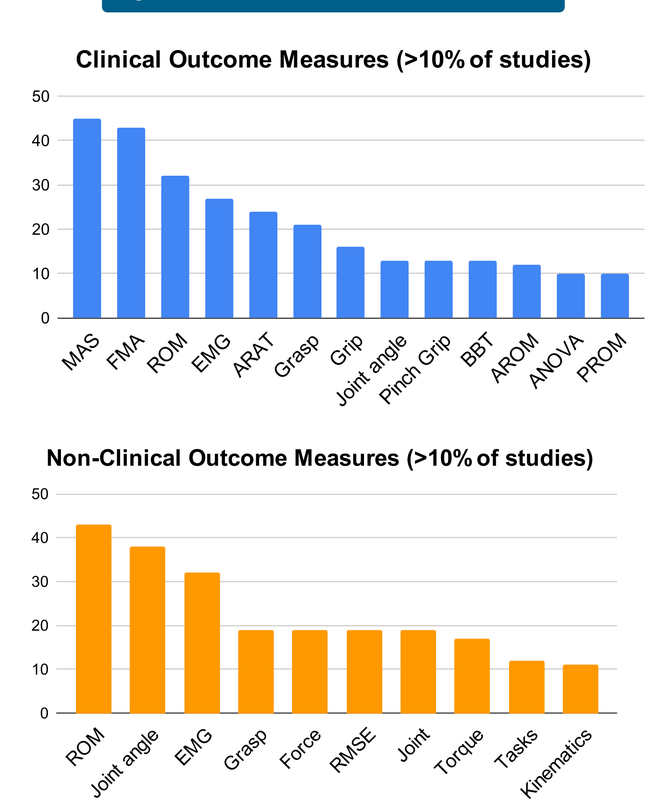
228 unique outcome measures were extracted. The most used outcomes were not reflective of clinical settings [8] and outcomes measures in studies which required **minimal setting up** were favoured (Figure 6). Patient recorded outcomes were often **unused** such as the **DASH outcome**.

Table 1: Abstracted User Intent Input

User Intent Methods	Count
EEG • Neural activity	**10**
EMG • EMG single threshold • EMG adaptive threshold	**37**
Joint movement • Digit movement* • Digit angle* • Wrist flexion/extension • Wrist supination/pronation • Tremor	**37**
Joint force (no digital interface) • Fingertip tactile force sensor • Digit torque* • Wrist torque	**29**
Manual Selection • Button, Switch, Joystick • User interface (PC, Mobile, Smartwatch) • Tongue position in mouth interface • Keyword selection from voice control • Foot position in insole interface	**24**

*All, combination, Index, or 5th

Figure 6: Bar chart of Outcome Measures



4. CONCLUSIONS

In this scoping review, we identified **135 primary studies** between 1995 and 2023.

Muscle stimulation and direct force transmission were the most popular design of the device. The target population of the devices was focused on **stroke affected persons**. The number of outcome measures was large and **not reflective of clinical settings**.

Efforts should be in **assessing clinical outcome measures** and **reducing cognitive load** by changing manual selection devices to more intuitive ones such as EEG, EMG and Joint induced.

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