Robotic assisted rehabilitation therapy for enhancing gait and motor function after stroke

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Stroke is a common, serious, and disabling global health-care problem and many patients, who survive from stroke, experience disabilities including gait abnormality or deficits in upper extremity control. Survivors also live with functional limitations in activities of daily living (ADL) and suffer life-long residual disability, requiring ongoing rehabilitation.

After neural injury such as stoke, the ability of the brain or neural network to change, named "neuroplasticity", is the basic mechanism of functional recovery. High-dose intensive intervention, through training and repetitive practice of specific functional tasks, are essential for neural network reorganisation and functional recovery.

> **During the last two decades there have been remarkable developments in robotic assisted rehabilitation therapy for promoting walking ability and upper extremity motor function.**

Rehabilitation robots for stroke can apply constant therapy for long periods and allow for continuous monitoring of patient performance and progression, that can be delivered to the therapist.

There are several types of rehabilitation robots, including exoskeleton and end-effector type robotic-assist systems. Exoskeletons resemble the human upper limb and robot joint axes match the limb joint axes. End-effector robots hold the patient's hands or feet at one point and generate forces at the interface.

Well-coordinated multidisciplinary stroke care, including comprehensive rehabilitation, combined with robot-assisted therapy works to provide a beneficial treatment option for motor recovery of the arm and gait.

There have been many studies into the benefits of rehabilitation robots in assisting patients who have suffered disability as a result of stroke. Whilst the results of the studies were varied, it is the general consensus that robot-assisted therapy on gait recovery delivered superior results in patients with subacute stroke, particularly when applied in combination with conventional physiotherapy compared with conventional therapy alone.

It was also concluded in a large participant study, that robot-assisted gait training with regular physical therapy produced promising effects on locomotor function in subacute stroke patients than regular physical therapy. In all studies, improvements were noted in gait speed, cadence, step length, and balance, as well as reducing the double limb support period. Further, robot-assisted therapy also showed improvements in arterial stiffness and increased peak aerobic capacity.

In patients looking to improve arm function and arm muscle strength after stroke, it was concluded that robotic assisted arm training improved ADL, function, and muscle strength of the affected arm. Robotic assisted therapy for hand motor function also delivered favourable to superior effects.

The main advantage of electromechanical or robotic assisted walking devices over conventional gait training, is that they reduce the need for intensive therapist support, have been shown to increase early independent walking after stroke, and could be also considered for patients who would not otherwise practice walking. Overall, the role of robotic assisted gait therapy in stroke rehabilitation is an adjunct to, rather than a replacement, for conventional rehabilitation therapy.

Whilst there were variations between the trials in the intensity, duration, and amount of training, type of treatment, participant characteristics, and measurements used, the quality of evidence was high, and has resulted in changes to the description for practice guideline in stroke rehabilitation.

Robotic assisted therapy for stroke rehabilitation has achieved remarkable advances in recent decades and holds considerable promise – however, they have not yet achieved strong clinical recommendations, due to barriers such as limited data on efficacy, financial constraints and lack of clinician familiarity with technology. Thus, ongoing improvements of the related technology, combined with further studies, will be required to clarify the best protocol for individual patient's need and its transferring effect to the real-world activities of patients.

Such advances, particularly during the age of the fourth industrial revolution, may enhance the clinical and economic efficiency of robotic assisted rehabilitation therapy and will lead to it becoming a standard therapeutic modality in stroke rehabilitation in the future.

Commentary: Robot-assisted stroke rehabilitation therapy

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Rehabilitation and assistive robots are on an uprise. More and more devices are being developed and becoming commercially available. The excitement around novel developments and possibilities, however, often comes with overwhelming options and confusing – at times even contradictory – outcomes. Reviews like this one consolidate information from multiple studies, enabling us to have a better overview of activities and knowledge in the field, and see where results may or may not generalise outside of individual studies. This commentary aims to provide further contextualising information, to support the interpretation of the paper's results. To facilitate visualisation, we graphically re-display part of the information from Tables 1 and 2 of the original paper as Figures in this commentary.

Robots – what is hard to see

Hardware

The idea of machines that support or augment human movement is not new; early exoskeleton-like devices were patented already in the late 1800s http://cyberneticzoo.com/early-teleoperators/. However, our ability to turn these devices into reality was limited by technology and our understanding of neurological recovery. To achieve the technical requirements, we could only build devices that were enormous, heavy, complicated and impractical. In the past few decades, the development of new actuators – smaller, lighter, more powerful – has allowed the field to take strides.

> **“In parallel, the breakthrough discovery that the brain is not hardwired but rather plastic, supporting the approach of relearning movements and not just compensatory strategies, further pushed the development of robots to support rehabilitation therapy.”**

As the author points out, the first lower-limb rehabilitation robots were big, stationary, and created to support therapist work during gait training. Traditionally, treadmill-based gait training of spinal cord injured patients requires 3 therapists – one to support the patient's body weight, and one to move each leg. Therapists could be off-loaded from strenuous tasks by exploiting robots for what they can do best – move each leg repetitively through the walking motions, and support the patient's weight. This can be achieved with exoskeleton-like devices that attach to the pelvis and legs (Lokomat), or through attachments at only a few places like the pelvis and feet (Gait trainer).

Upper-limb therapy robots, on the other hand, were first derived from movement neuroscience research. As such, most upper-limb robots initially focused on recovery (i.e. relearning) not assistance (i.e. replacement of abilities that cannot be recovered). As our understanding of the field evolved, promoting neurological recovery of the patient has been the biggest driver in the development of all types of robots for therapy.

As technology improves, we have seen the emergence of wearable exoskeletons: devices that are self-contained and worn by users moving in the environment. Lower-limb exoskeletons tend to be used for patients with less gait impairments, since they do not require as much body weight support. However, these devices are usually designed for specific gait deficits or patient populations, which greatly influences their capabilities. Different devices can support different combinations of joint movements – for example, only the hip (Honda SMA; GEMS), hip and knee (Hybrid Assistive Limb), or only the ankle (Anklebot). Similarly to the lower-limb devices, advances in technology have allowed the development of smaller and portable upper-limb devices, albeit they are still technically very challenging thus fewer.

As is likely becoming clear, differences in hardware make it difficult to compare outcomes from studies using different devices. Even when devices are similar, for example supporting movements of the same joints, the particularities of their designs change characteristics that are inherent to the device (for example, its weight and how the weight is distributed within the device), which will affect its ability to support different activities. Each device can also be adjusted to the size or body shape of different users, fitting some better than others – thus, even comparing the same device across users should be done with care.

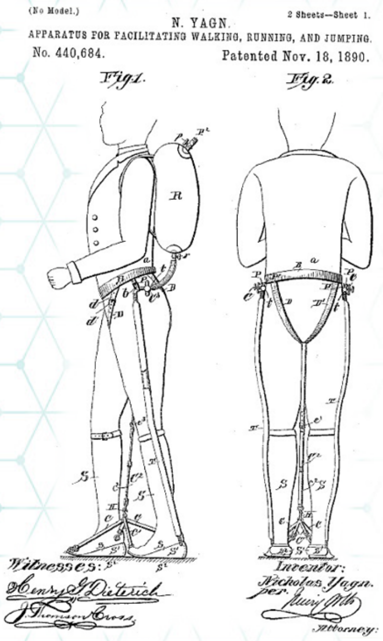

Figure 1: 1890 – Assisted-walking Device – Nicholas Yagn (Russian)

Control

To further accommodate the abilities of individual users, most robots that support movement have many parameters that can be modified to influence their behaviour to best serve the activity being done. A prime example of this is the concept of 'assist-as-needed', born from the realisation that passive movement alone – as was done by the first rehabilitation robots – is not enough to promote neurological recovery and regain active control of movements; the user needs to be trying to move to be able to harness neuroplasticity and motor learning. This means that the robot should not be driving the movement, but rather follow the user's lead and only interfere when the user needs support to complete the intended motion.

Interaction between machines and humans, however, is not easy to realise in practice. Understanding when users need to be supported and how much support to provide, while keeping the user safe, is a challenge. Many groups are working hard on allowing interactions to happen in a smooth and intuitive way (intention detection, shared control, assist-as-needed). On the flip side, a safe but poorly controlled interaction could be counter-productive and train users to make inadequate movements, or lose their ability to move correctly. Thus far, studies and systematic reviews point to no detrimental effects from using robots.

Are robots effective in promoting recovery?

The effectiveness of robot-assisted therapy has been a controversial issue. Systematic reviews over the last 10 years have reported mixed evidence supporting their use to promote functional recovery. The lack of solid evidence that robot-assisted therapy can offer greater functional improvement than dose-matched conventional therapy has split the opinion in two. For many, this has discouraged their use and adoption in the clinical practice; they expect robotic devices to deliver better results than traditional care. For others, these results have instead encouraged their adoption and support of new concepts such as robotic rehabilitation gyms, since their use has been proven safe and not detrimental to recovery.

However, we cannot analyse the efficiency of robot-assisted therapy as we commonly do with, for example, pharmaceutical interventions. Robots, per se, are not an intervention – robots are tools. The concept of 'robot-assisted therapy' is vague, due to the huge number of possible hardware/control combinations—a few of which were described above.

> **"In our opinion, there must be a shift about the way we talk about the topic of robot-assisted therapy, and instead, focus on understanding interventions based on their neuroscientific bases."**

There is still a lot of debate about the role of therapy dosage (how much time or how many repetitions), intensity (dose per session), and timing during recovery to promote the best outcomes for stroke survivors – which is not isolated to robotic therapy, but relates to stroke rehabilitation as a whole (Senesh & Reinkensmeyer, 2019; Ward, Brander, & Kelly, 2019). Because of this, it is important to consider the protocol used in each study, as well as parallel participation in other therapy programs – as is mentioned in this review. Nonetheless, results are still inconsistent, and suggest that further studies are needed to better understand how different elements interact and can be exploited to provide the best outcomes.

Robots for rehabilitation – outlook

Besides therapy, robots can be used to create efficient clinical settings at multiple levels. Robots have the potential to increase therapy time; allow healthcare professionals to manage multiple patients simultaneously while still creating personalised therapies for each; facilitate training opportunities when healthcare personnel are not directly available (e.g., weekends or during idle time); or enable tele-rehabilitation scenarios for remote communities or home delivery.

We believe that robots will fundamentally change the way we diagnose and assess physical impairments. Robotic devices have many embedded sensors, which are need for their control. They can measure parameters beyond what can be observed with the naked eye, extending the ability of clinicians to assess their patients.

These measurements could enable real-time feedback of performance to the user, as well as monitoring how they progress through therapy. This does not mean that a robot will completely replace a clinician in the clinical evaluation process; clinicians have access to the patient history and other parameters to which the robot is blind to. Robots are tireless, and excel in precise and accurate measurements and repetitions.

> **"It will be the combination of human and machine expertise that will become an essential component in the diagnosis and assessment of patients."**

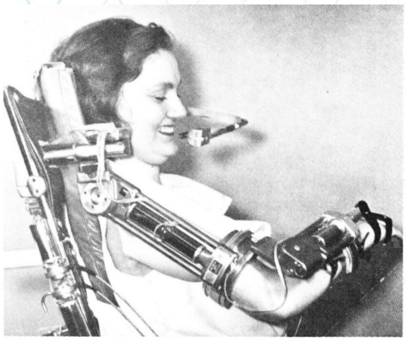

Figure 2: The Rancho Los Amigos Orthosis from 1977 [adapted from cyberneticzoo.com].

A challenge here is that, in the majority of cases, these sensor-based measurements are very different from clinical assessments, so it is important to understand how to interpret these or derived values in a clinically meaningful way (Shirota et al., 2017).

There is no question that robotics is already impacting clinical practices and will continue to play a fundamental role in all facets of patient care. However, current advances in robotics for rehabilitation and technological innovations are, mostly, technology-driven, and there is still a long way to optimise these devices for maximum benefit of both patients and clinics.

To solve this, we think there needs to be a fundamental shift about how we think and evaluate these technologies. The first shift must be about the way we talk about the topic of robot-assisted therapy, and instead, focus on understanding interventions based on their neuroscientific bases (regardless of being robotic or non-robotic) - we should always remember that robots are just another tool to support the delivery of rehabilitation interventions. Secondly, as these devices prove their worth in research studies and migrate towards real-life clinical and everyday use, they also need support to establish economical value (Pinto et al., 2020).

> **Finally, if we want to see these developments reach their intended end-users, we need to foster transdisciplinary and multi-stakeholder approaches to therapy and technological innovation, working together to make a case for solutions that are valuable to all.**
>
> (Kendall et al., 2019; Shirota, Balasubramanian, & Melendez-Calderon, 2019)

The clinic of the future should include biomedical engineers as an integral part of the clinical team. In parallel, clinicians, users and other non-engineering professions need to be included—from the start—in applied technology projects.

These cross-exposures, which are crucial to the advancement of this field, can create opportunities for educational programs at and exchanges with universities – creating a dynamic that will foster the development of technology that is user-driven. This will, with no doubt, enrich clinical reasoning by adding a different dimension to the understanding of impairments in everyday practice, and help us get closer to achieving our end-goal that is the recovery of patients.

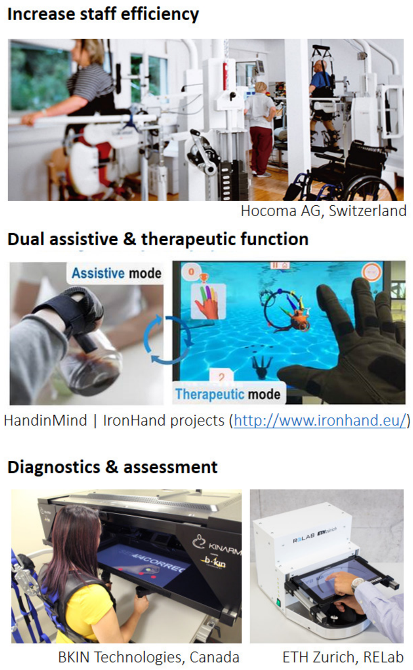

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Figure 3: Besides therapy, robots can impact clinical practice in a variety of ways.

References

Kendall, E., Oh, S., Amsters, D., Whitehead, M., Hua, J., Robinson, P., . . . Lightfoot, B. (2019). HabITec: A Sociotechnical Space for Promoting the Application of Technology to Rehabilitation. Societies, 9(4). doi:10.3390/soc9040074

Pinto, D., Garnier, M., Barbas, J., Chang, S. H., Charlifue, S., Field-Fote, E., . . . Heinemann, A. W. (2020). Budget impact analysis of robotic exoskeleton use for locomotor training following spinal cord injury in four SCI Model Systems. J Neuroeng Rehabil, 17(1), 4. doi:10.1186/s12984-019-0639-0

Senesh, M. R., & Reinkensmeyer, D. J. (2019). Breaking Proportional Recovery After Stroke. Neurorehabil Neural Repair, 33(11), 888-901. doi:10.1177/1545968319868718

Shirota, C., Balasubramanian, S., & Melendez-Calderon, A. (2019). Technology-aided assessments of sensorimotor function: current use, barriers and future directions in the view of different stakeholders. J Neuroeng Rehabil, 16(1), 53. doi:10.1186/s12984-019-0519-7

Shirota, C., van Asseldonk, E., Matjacic, Z., Vallery, H., Barralon, P., Maggioni, S., . . . Veneman, J. F. (2017). Robot-supported assessment of balance in standing and walking. J Neuroeng Rehabil, 14(1), 80. doi:10.1186/s12984-017-0273-7

Ward, N. S., Brander, F., & Kelly, K. (2019). Intensive upper limb neurorehabilitation in chronic stroke: outcomes from the Queen Square programme. J Neurol Neurosurg Psychiatry, 90(5), 498-506. doi:10.1136/jnnp-2018-319954

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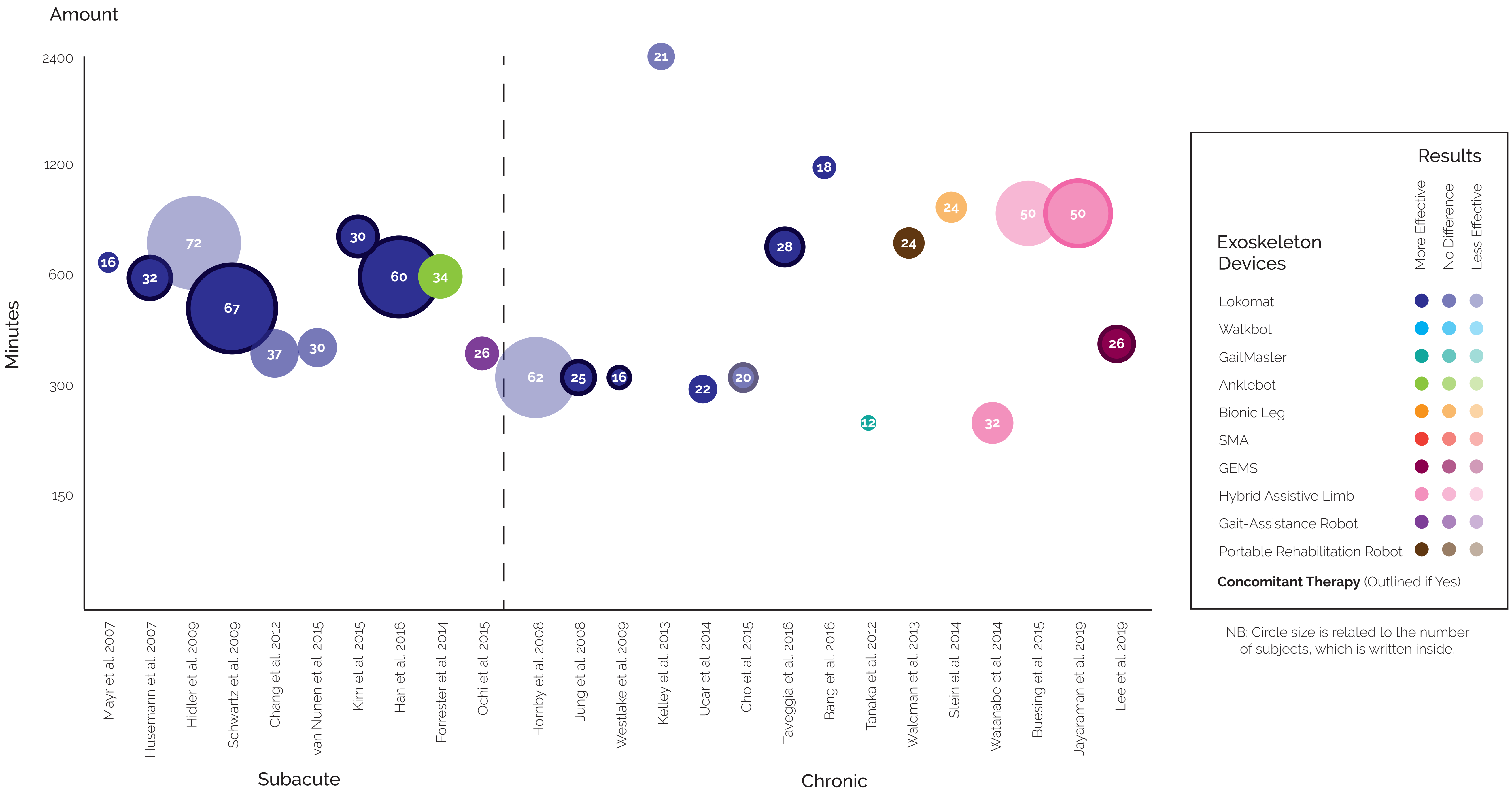
Table 1: Summary of robotic or electromechanical-assisted gait training (Exoskeleton Devices)

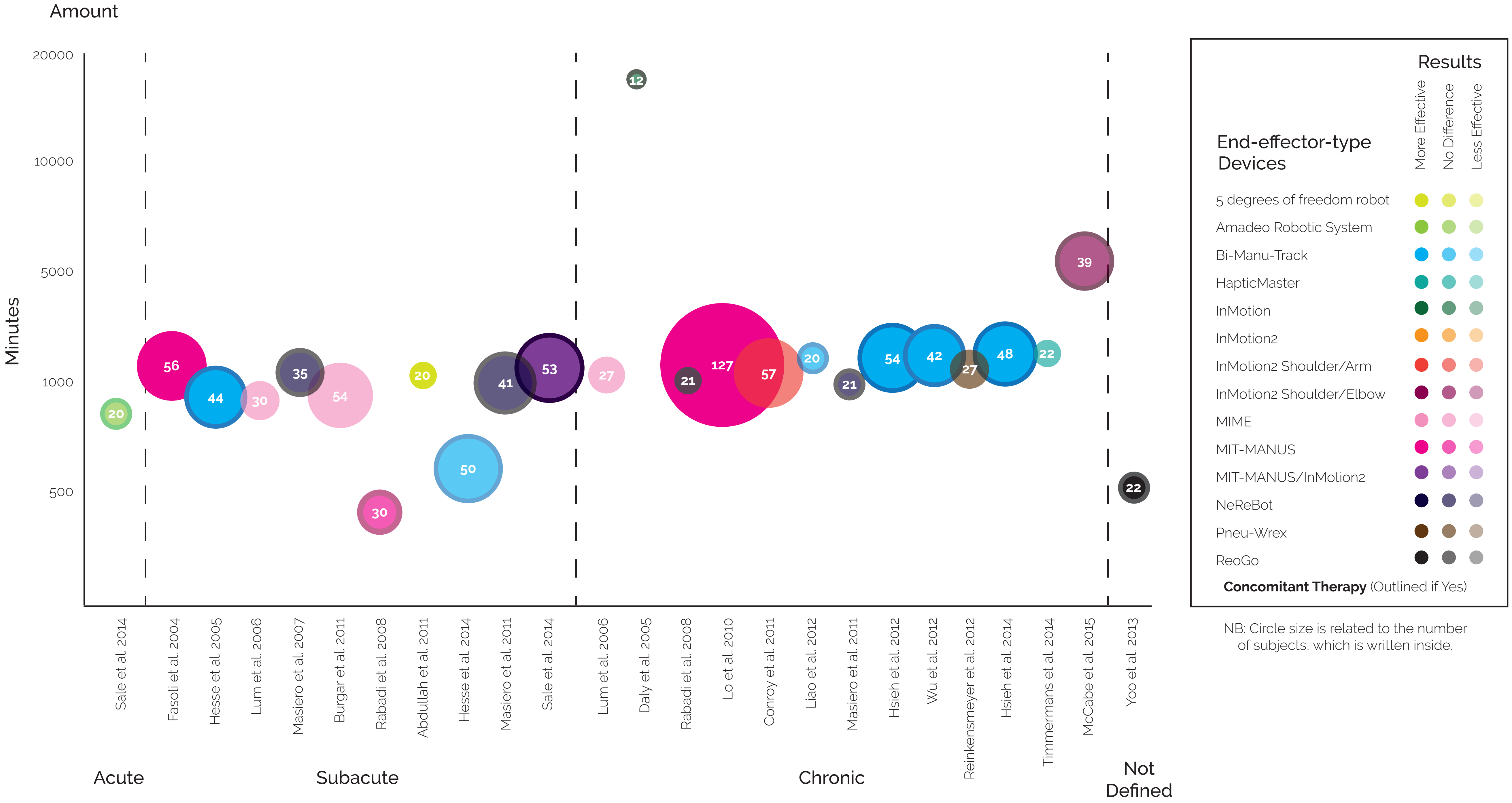
Results in comparison with conventional therapies



NB: Circle size is related to the number of subjects, which is written inside.

Table 2: Summary of robotic or electromechanical-assisted training for upper limb motor function (End-effector-type devices)

Results in comparison with conventional therapies



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