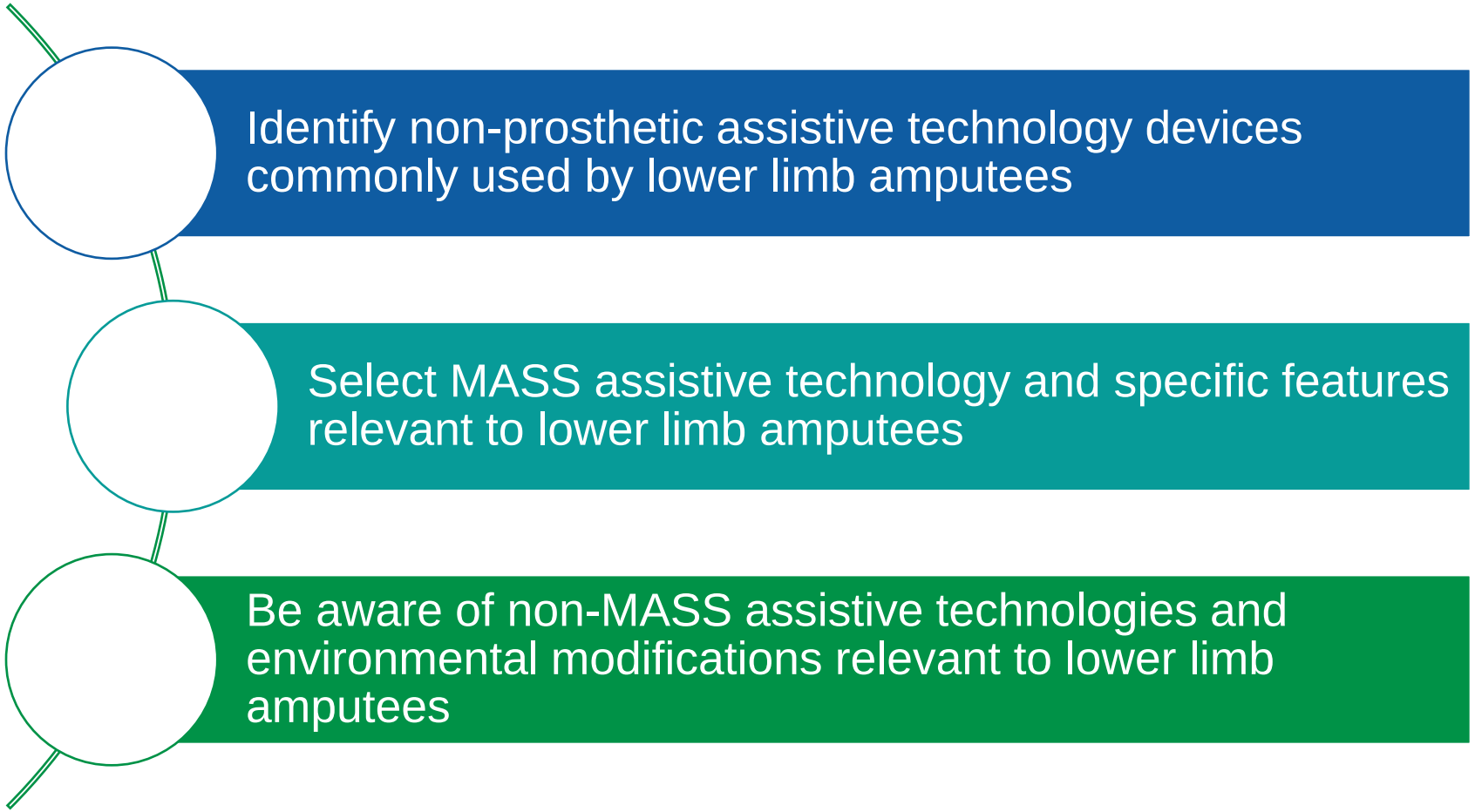
Assistive technology for lower limb amputees – more than just a prosthesis

Queensland Government

Medical Aids Subsidy Scheme
19 September 2024

Learning objectives



90% of amputations for older people (over 65yo) are related to vascular issues[1]

54% of lower limb amputees use a wheelchair after rehabilitation, higher for those with dysvascular amputation[2]

18.4% of dysvascular amputees have cognitive impairment (MMSE score < 23)[1]

The mean survival of older people after amputation ranges from two to five years[3]

1. Fleury, A.M., Salih, S.A., & Peel, N.M. (2013). Rehabilitation of the older vascular amputee: a review of the literature. *Geriatrics & Gerontology, 13*, 264-273.
2. Batten, H.R., et al. (2015). Demographics and discharge outcomes of dysvascular and non-vascular lower limb amputees at a subacte rehabilitation unit: a 7-year series. *Australian Health Review, 39*, 76-84.
3. Spiliotopoulou, G., & Atwal, A. (2012). Is occupational therapy practice for older adults with lower limb amputations evidence-based? *Prosthetics & Orthotics International, 36*(1), 7-14.

K-level	K-level descriptor	Percent attending outpatient prosthetic clinic[1]	Percentage receiving amputation in hospital[2]
0	…a prosthesis does not enhance their quality of life or mobility	0%	36%
1	…use a prosthesis for transfers or ambulation on level surfaces…	7%	54% (K1&2)
2	…ability to traverse low level environmental barriers such as curbs, stairs, or uneven surfaces	78%	
3	…ability to traverse most environmental barriers and may have vocational, therapeutic, or exercise activity…	15% (K3&4)	10% (K3&4)
4	…high impact, stress, or energy levels. Typical of the prosthetic demands of the child, active adult, or athlete		

1. Majdič, N., Vidmar, G., & Burger, H. (2020). Establishing K-levels and prescribing transtibial prostheses using six-minute walk test and one-leg standing test on prosthesis: a retrospective audit. *International Journal of Rehabilitation Research, 43*(3), 266-271.
2. Yilmaz, M., et al. (2016). The effect of amputation level and age on outcome: an analysis of 135 amputees. *European Journal of Orthopaedic & Surgical Traumatology, 26*, 107-112.

Video by Onefootedpheonix

Video by Cut Above the Knee

Problems with prostheses[1]

Poor fit

"It should fit like a glove and the way I felt with the stump going into that socket, it felt like it was going in to a bucket… And when I go up and I do a bit of work around the farmyard, doing the bare minimum… I'd have to come home and take the leg off. If just didn't feel comfortable, it didn't feel part of me."

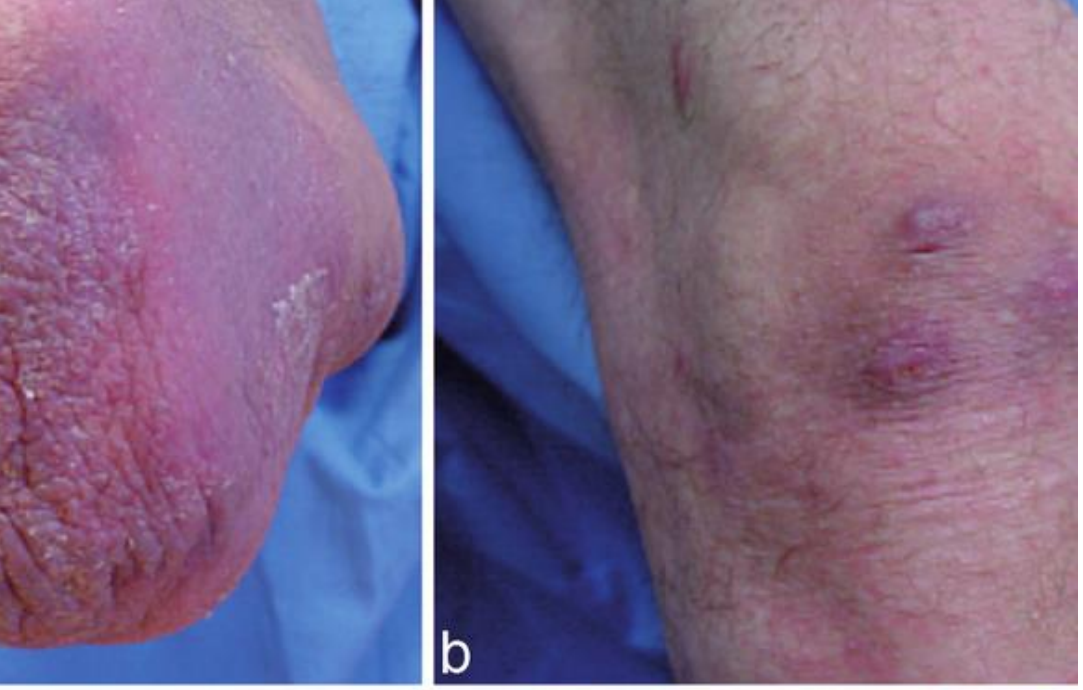
Discomfort

"I don't wear the prosthetic very much, it hurt a lot and it is a bit awkward. I go to the gym twice a week and I wear it over there. I wear it here an odd time too but I find it quite uncomfortable. I should be wearing it more, put it that way."

Limited mobility

"I couldn't master [using the prosthesis]… The first time I put it on me, I had a frame and I feel right back on my back; I hurt my back, I lost my balance on it. It is too awkward; the knee can bend without you wanting it to bend."

Dunne, S., Coffey, L., Gallagher, P., Desmond, D., & Ryall, N. (2015). Beyond function: using assistive technologies following lower limb loss. *Journal of Rehabilitative Medicine, 45*, 47.



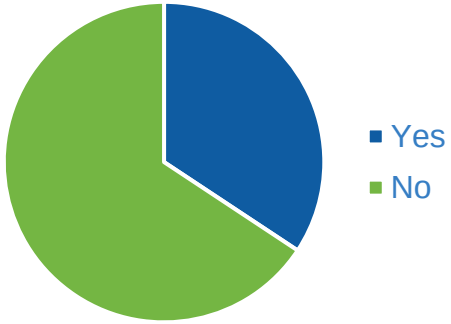
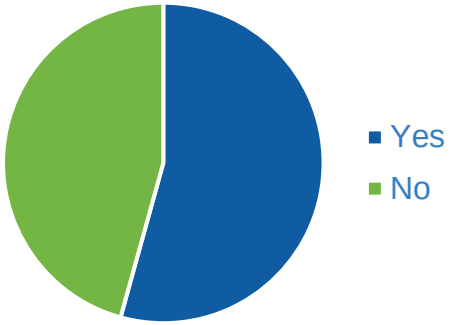
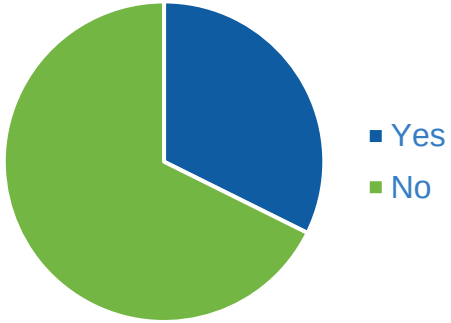
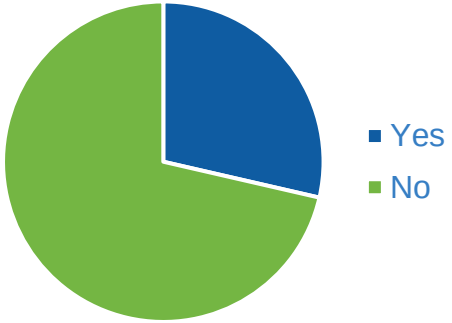
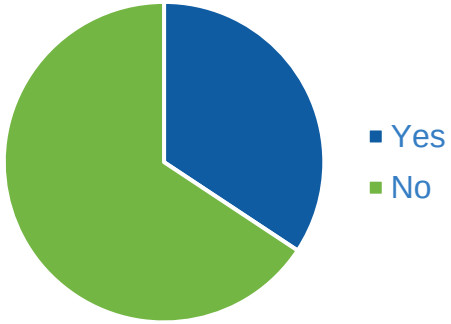
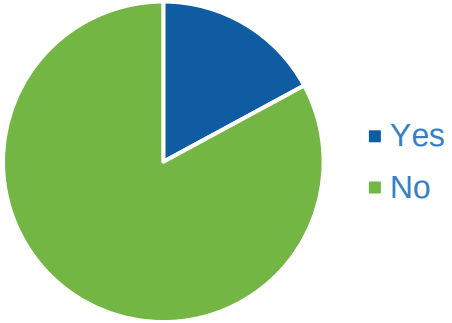
Stump skin problems

- Point in time prevalence may be around 16%[1] to 36%[2]
- Prevalance in the past year for people with an amputation more than 38 years old – 48.2%[3]
- More common with use of antibacterial soap, smoking, and washing the stump 4 times a week or more, being younger, and use of a walking aid (some skin problems only).[4]

1. Meulenbelt, H.E.J., et al. (2006). Skin problems in lower limb amputees: a systematic review. Disability & Rehabilitation, 28(1), 603-608.
2. Meuelenbelt, H.E.J., et al. (2011). Skin problems of the stump in lower limb amputees: 1. A clinical study. Acta Dermato-venereological, 91(2), 173-177.
3. Yang, N.B., Garza, L.A., & Foote, C.E. (2012). High prevalence of stump dermatoses 38 years or more after amputation. JAMA Dermatology, 148(11), 1283-1286.
4. Meuelenbelt, H.E.J., et al. (2009). Determinants of skin problems of the stump in lower-limb amputees. Archives of Physical Medicine & Rehabilitation, 90(1), 74-81.
5. Image from: Meulenbelt, H.E.J., et al. (2011). Skin problems of the stump in lower limb amputees: 1. a clinical study. *Acta Dermato-Venereologica, 91*(2), 173-7.

sockets vs osseointegration

Image from: 1) Amputee Store 2) CBS News

		In the home	In the community
Prosthesis			
Wheelchair			
Crutches or walker			

Vetrayan, J., et al. (2016). Occupational performance role and satisfaction among lower limb amputees with different adaptive devices usage. *Procedia – Social & Behavioural Sciences, 222*, 432-441.

MASS data – 3 years

Number of clients† receiving	#
Above knee prosthetics through QALS	155
Below knee prosthetics through QALS	617
SP manual wheelchair with pressure cushion	229
Bath transfer bench	100
Mobile shower commode	80
Wheeled walking aid	78
Powerdrive wheelchair with pressure cushion	46
Continence products	38*
Pressure redistribution mattress	29

† with lower limb amputation as the primary diagnosis

* Similar rate to persons without amputation

MAIS, 01/09/21-30/08/24

Deep dive into MASS statistics

1034 lower limb amputees (excluding partial feet) or which 76% received a QALS limb.

Of those receiving a QALS limb or service within the last 3 years, during that time;

- 13% received at least one mobility aid
  - 1.3% received a PWC
  - 1.9% received a 4WW
  - 10.4% received a SP MWC
  - No significant difference in rates between above and below knee amputees
- 2.3% received a MSC
- 3.9% received a bath transfer bench

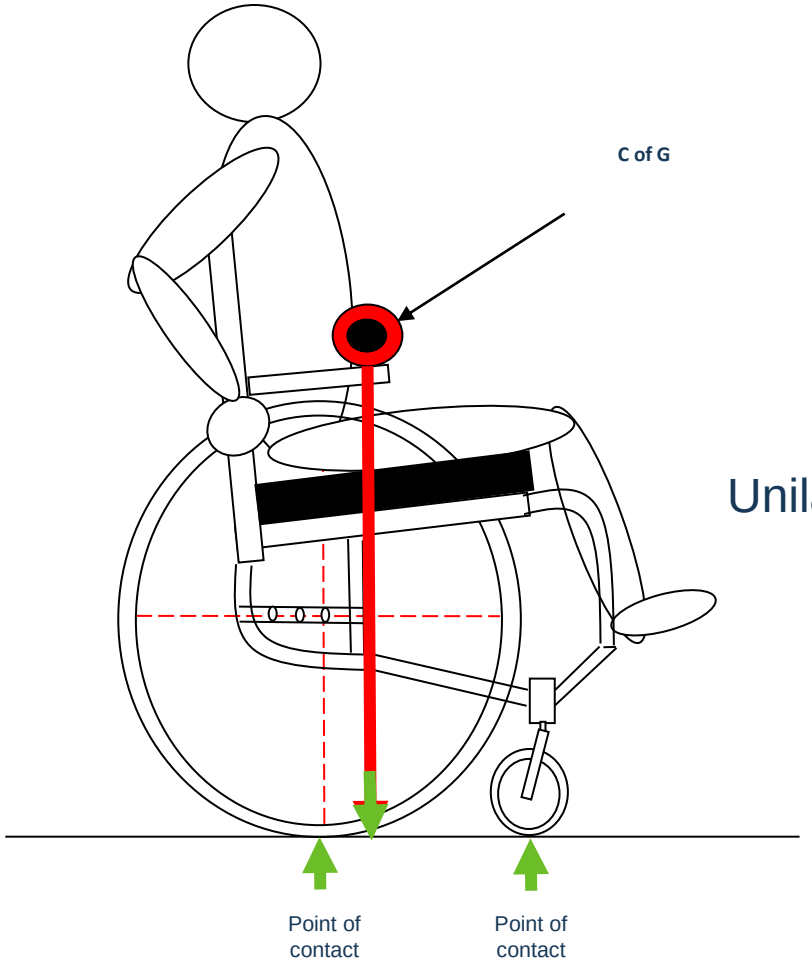
Manual wheelchair setup – safety & propulsion

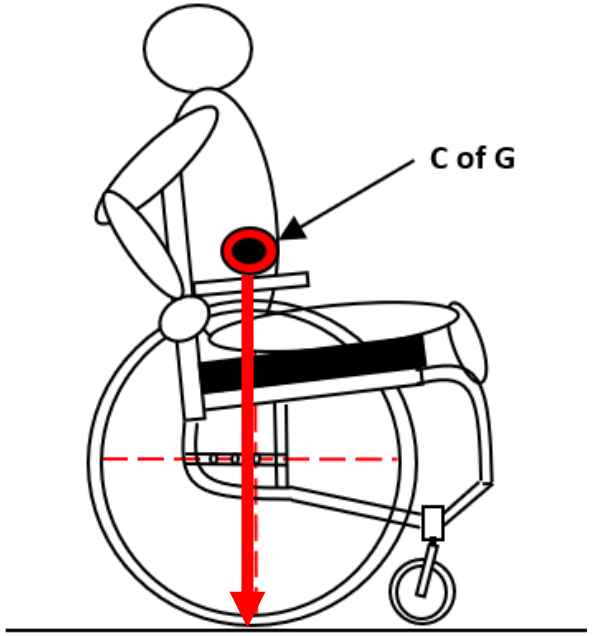
Axle position

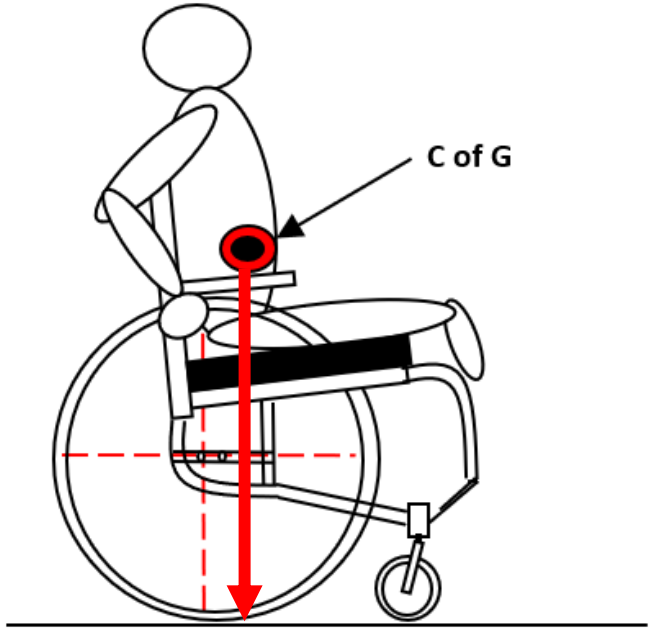
Anti-tips

Pressure cushion height

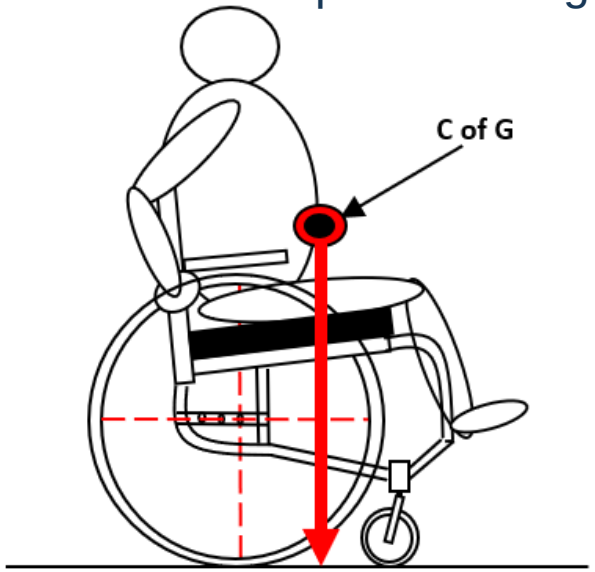
Images from: 1) Sunrise Medical 2) Melrose Wheelchairs 3) Forte Healthcare

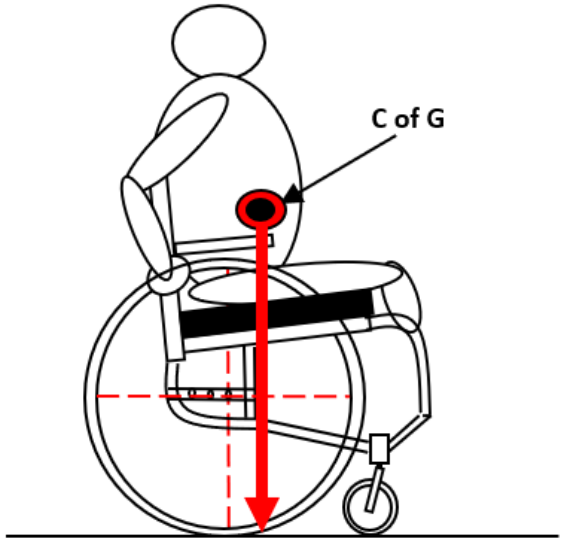




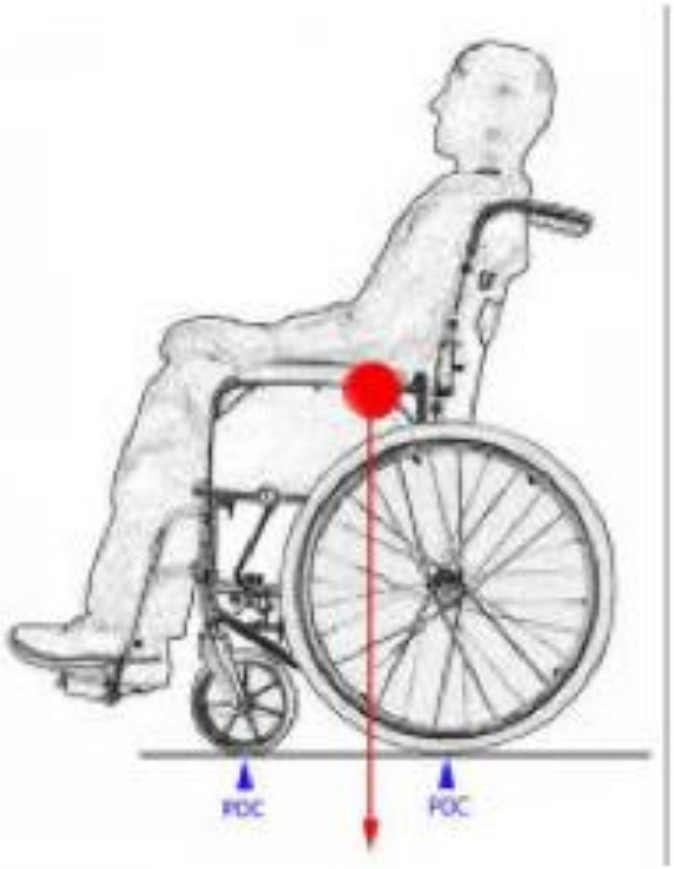


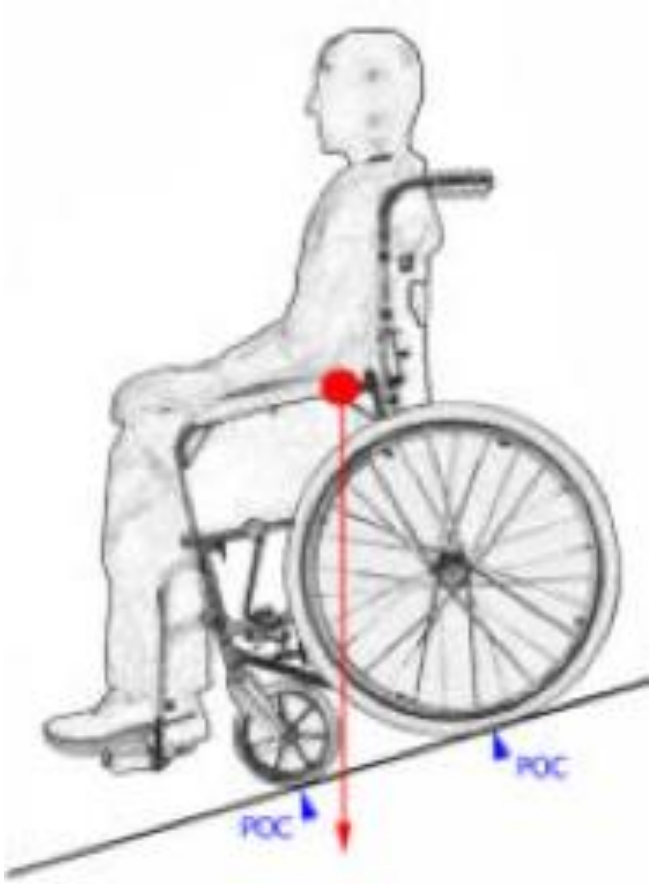
Unilateral / bilateral? Amputation height?

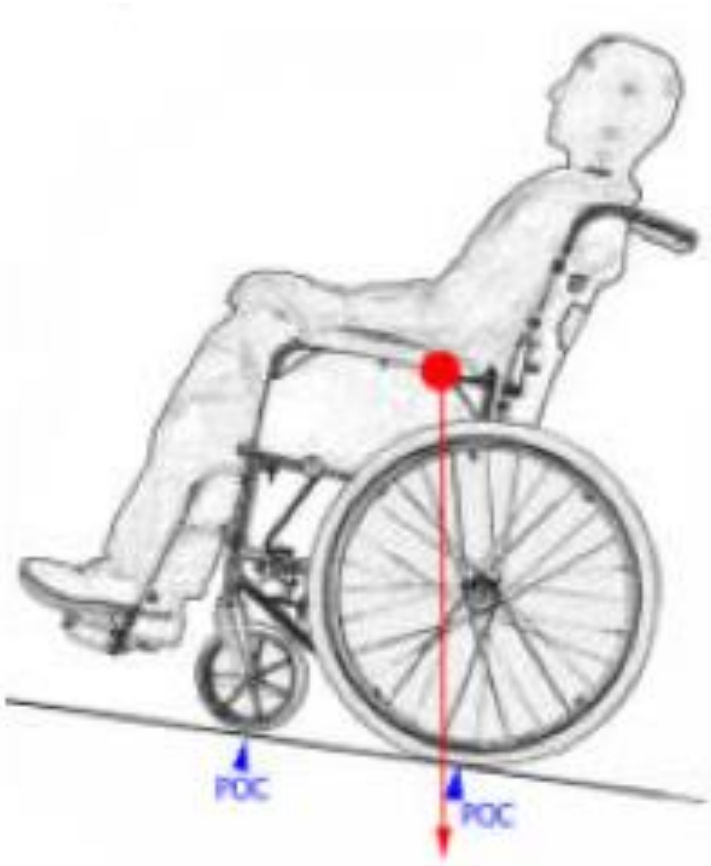




COG: Center of gravity







https://meamseniordesign.wordpress.com/2012/01/19/stability-analysis/

POC: Point of contact between wheel & ground

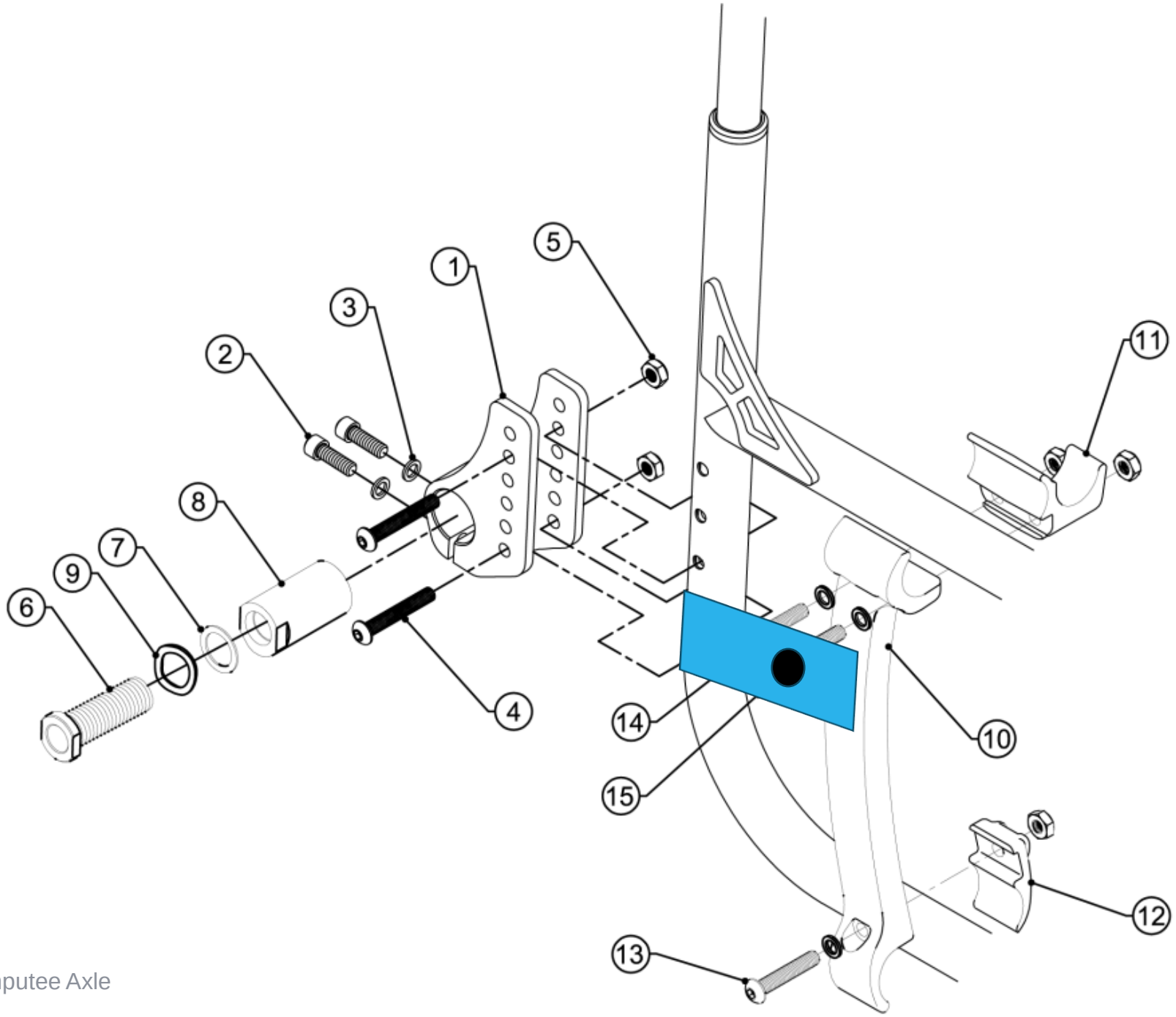
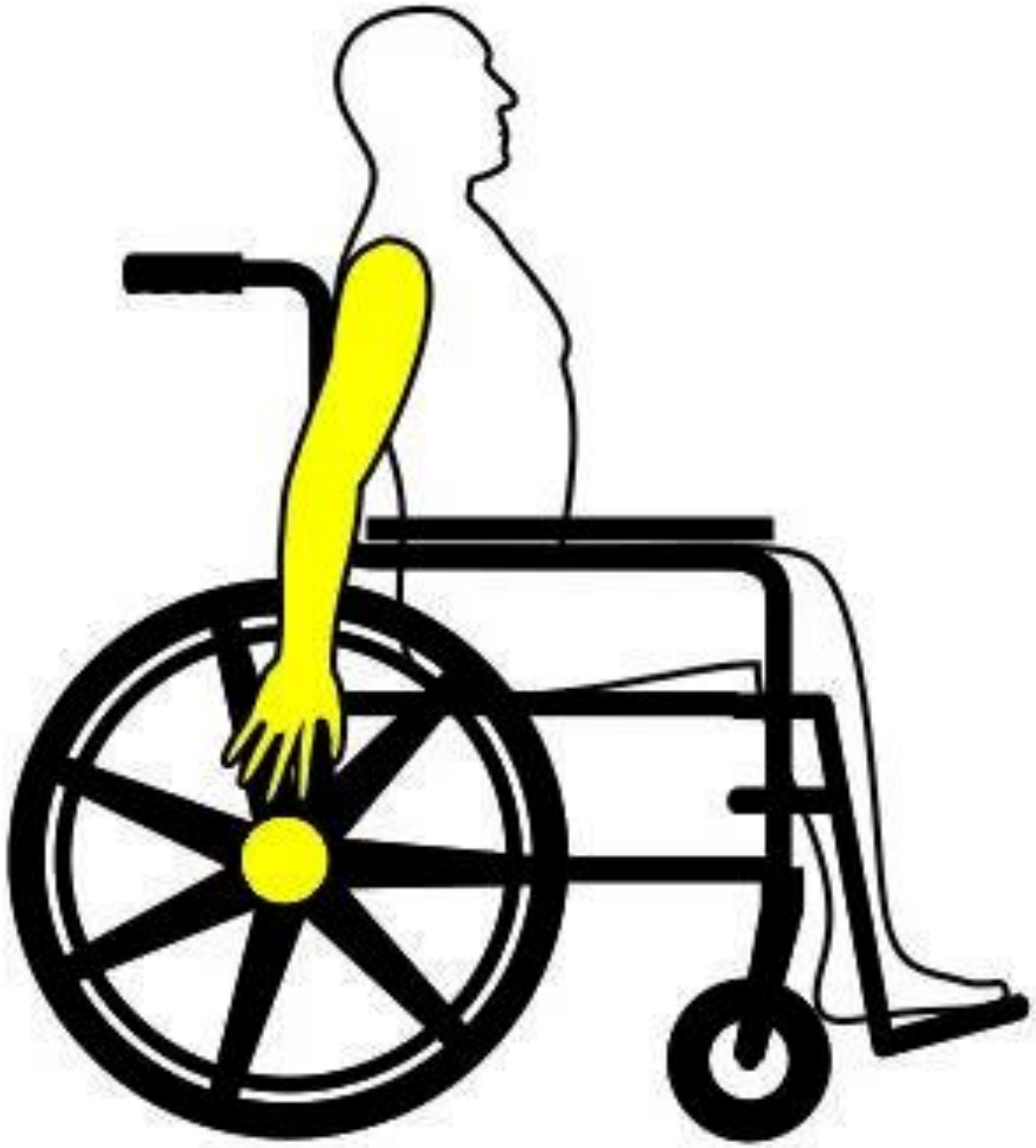


Image: Tilite 2GX Amputee Axle



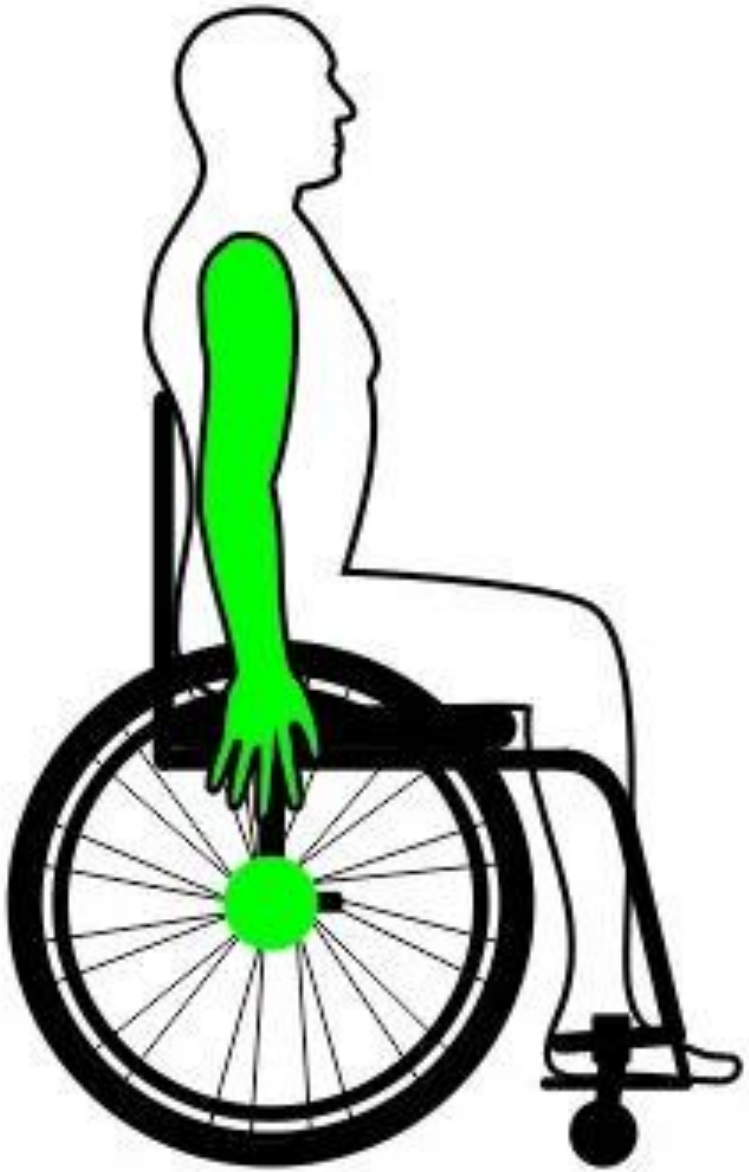
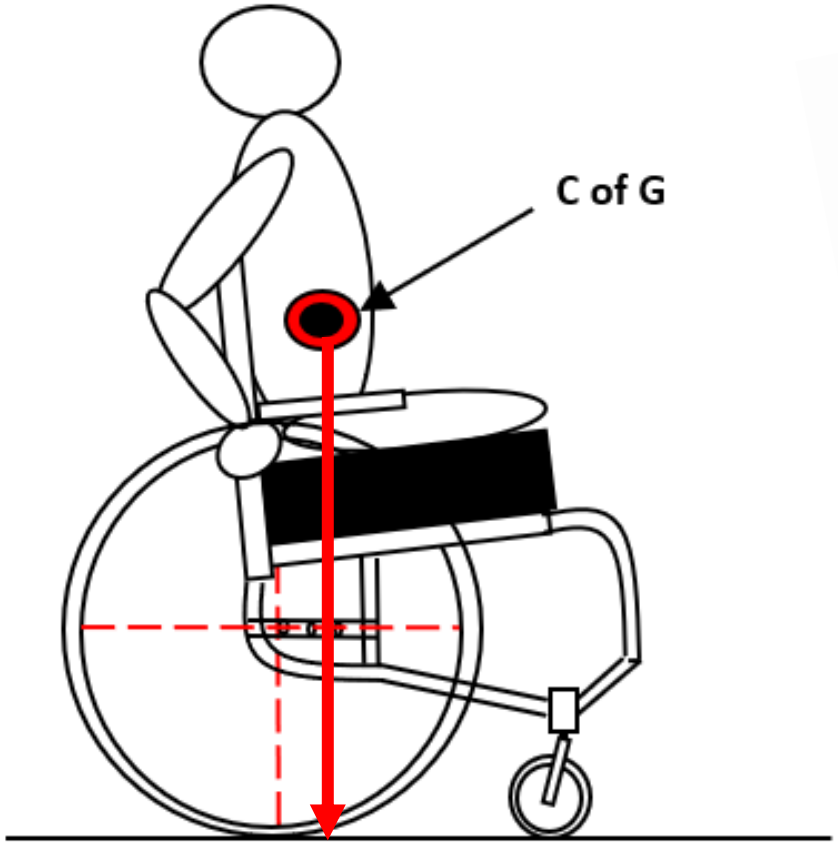
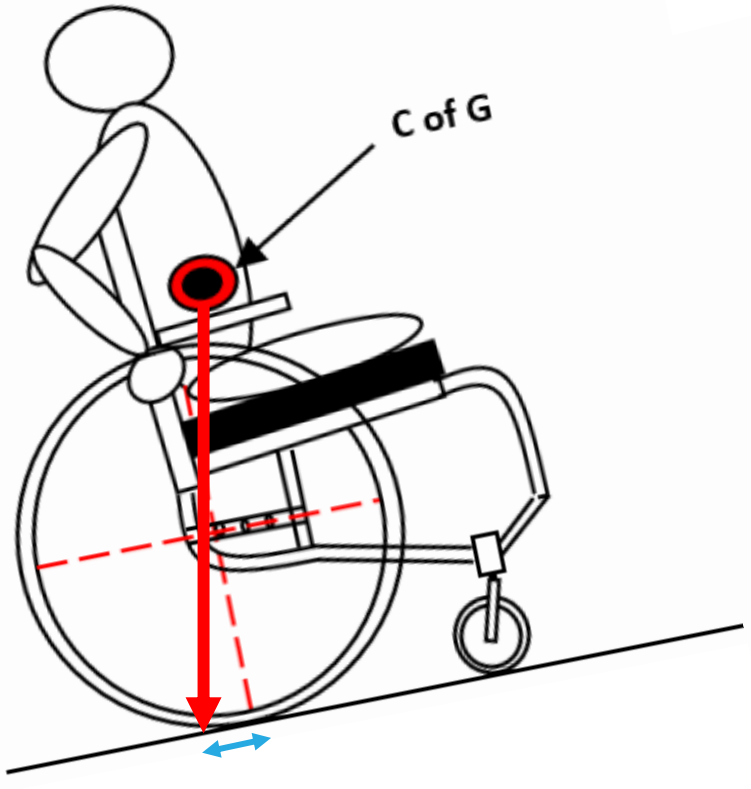
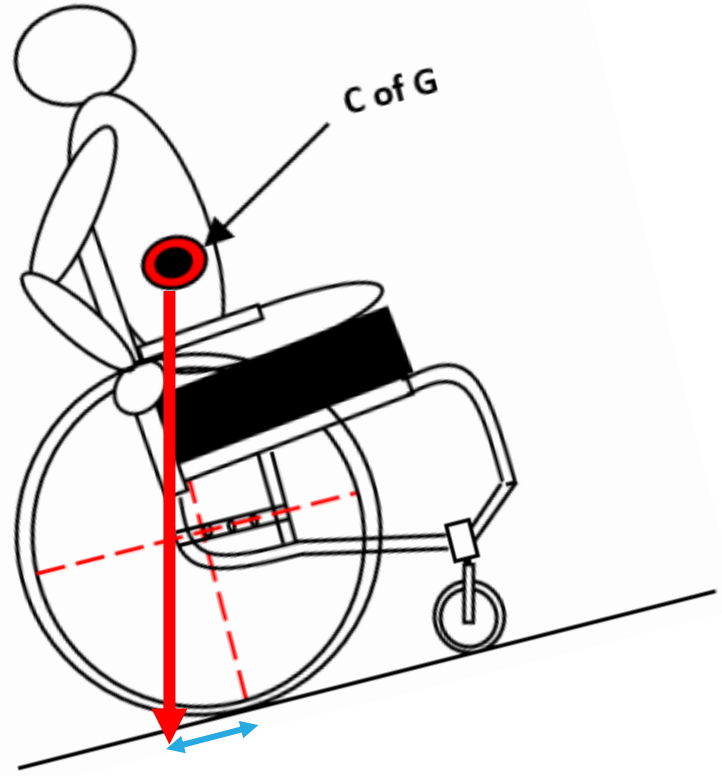


Image from: Loh Medical

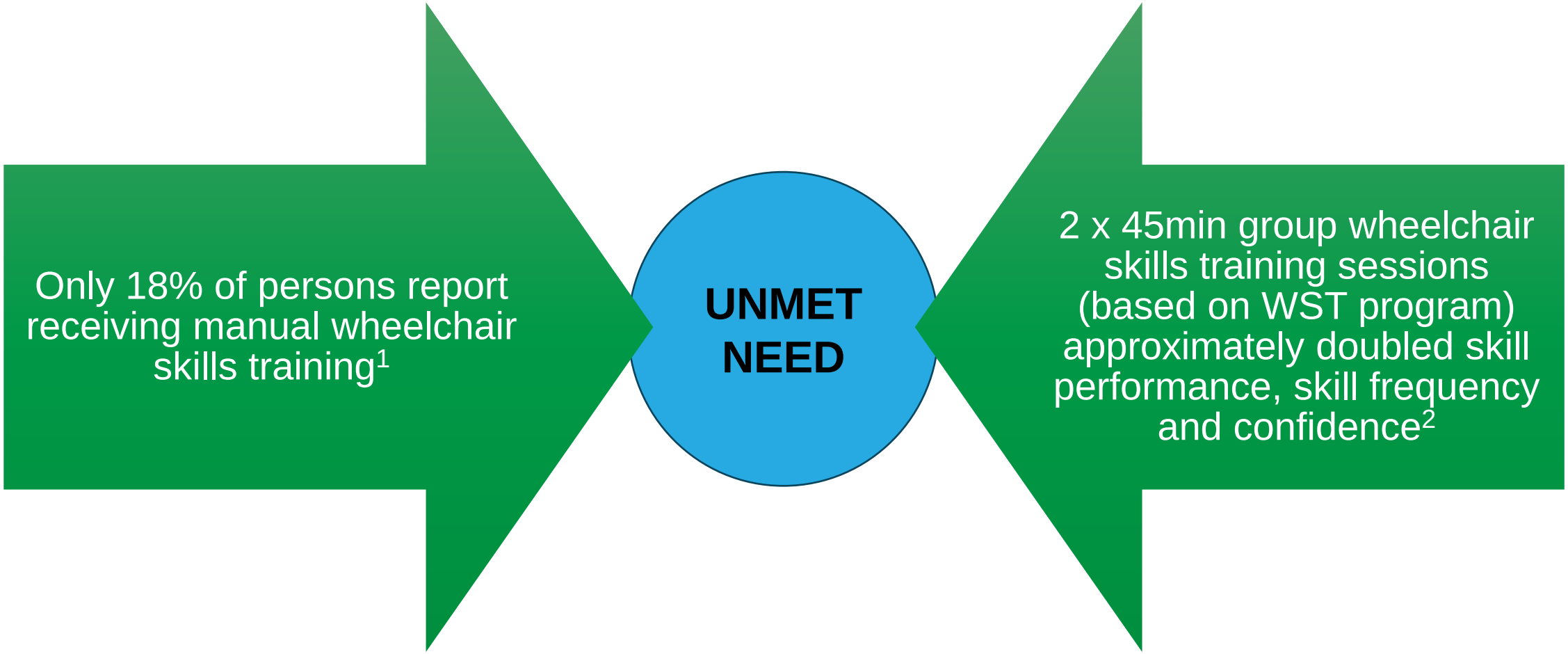
Cushion height and centre of gravity







Manual wheelchair training



1. Karmarkar, A.M., et al. (2009). Prosthesis and wheelchair use in veterans with lower-limb amputation. *Journal of Rehabilitation Research & Development, 46*(5), 567-576.
2. Charlton, K., et al. (2021). Facilitating manual wheelchair skills following lower limb amputation using a group process: a nested mixed methods pilot study. *Australian Occupational Therapy Journal, 68*, 490-503.

Manual wheelchair setup – stump support and seat angle

Stump supports are typically recommended by therapists, but are based on **weak evidence** [1,2,3]

Reasoning focuses on prevention of flexion **contracture**, **oedema** management, stump **protection** and **comfort** [1]

Stump support is vital in the first two weeks post-surgery [4]

Also consider seat angle and potential impact on hip flexion contracture [5]

Contractures may be reducible with regular prosthetic use (case study evidence) [4]

1. Parker, K., et al. (2023). Residual limb support devices on wheelchairs for people with transtibial amputations: A scoping review and survey of rehabilitation professionals in Nova Scotia. *Prosthetics & Orthotics International, 47*(4), 387-398.
2. Kirby, R.L. et al. (1999). *Wheelchair drop-seat slotboard to support the residual limb of people with transtibial amputations: short-term experience*. Paper presented at RESNA '99, Jun 25-29.
3. Spiliotopoulou, G., & Atwal, A. (2012). Is occupational therapy practice for older adults with lower limb amputations evidence-based? *Prosthetics & Orthotics International, 36*(1), 7-14.
4. Hanafi, M.H., et al. (2017). Improvement of knee flexion deformity in transtibial prosthetic user. *International Medical Journal, 24*(4), 343-344.
5. Poonsiri, J. et al. (2022). Fitting transtibial and transfemoral prostheses in persons with a severe flexion contracture: problems and solutions – a systematic review. *Disability & Rehabilitation, 44*(15), 3749-3759.

Popular MASS MWCs for amputees

Ki Catalyst 4
- ✓ Rear axle adjustment
- ✓ Seat height adjustment
- ✓ Amputee bracket
- ✓ Stump support

Aspire Evoke 2
- ✓ Rear axle adjustment
- ✓ Seat height adjustment
- ✓ Amputee bracket
- ✓ Stump support

Action 3NG
- ✓ Rear axle adjustment
- ✓ Seat height adjustment
- ✓ Amputee bracket
- ✓ Stump support

Breezy BasiX 2
- ✓ Rear axle adjustment
- ✓ Seat height adjustment
- ✓ Amputee bracket
- ✓ Stump support

Pressure cushion considerations

Unilateral / asymmetric

- Less weight on lower leg/s (with / without prosthesis)
- Less lever forced applied on knee
- Less weight transferred through thigh/s
- Pressure asymmetry

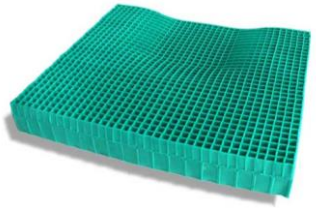
AKA

- AKA: Short residual limbs length
- Less area to off-load to
- Off-loading cushions unlikely to work
- Immersive & stable

Top 4 MASS prescribed cushions for amputees*

Matrx Libra

Axiom SPF/SPV (frequent in BK amputees)



Equagel

Varilite

* MAIS data, past 3 years

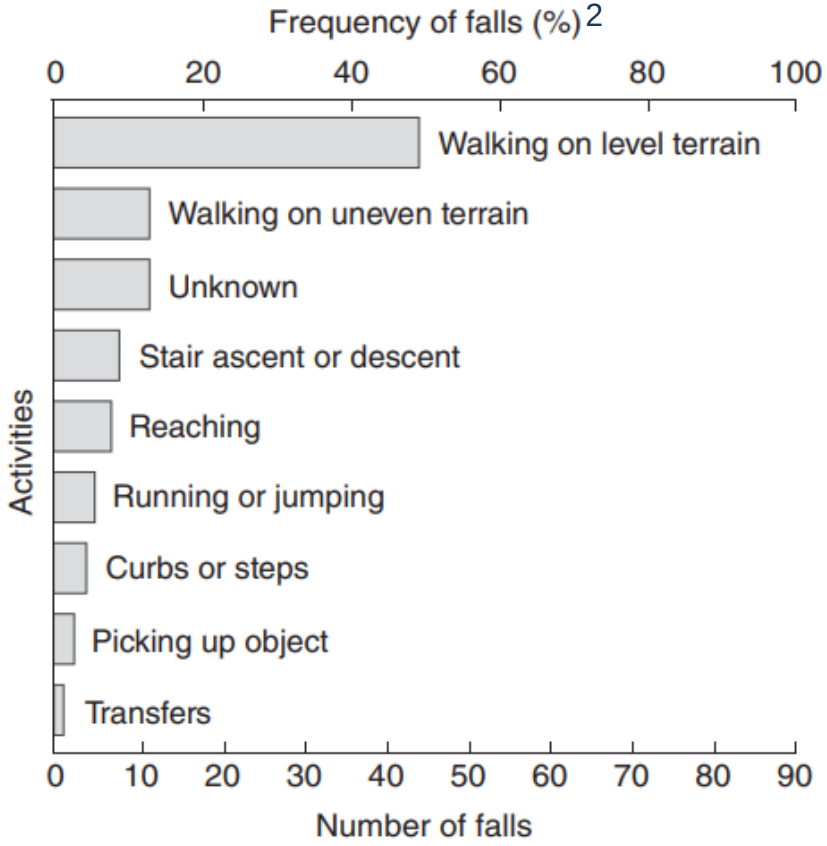
Difficulty activities

- Walking, e.g., long distance & uneven terrains
- Ramps and slopes[1]
- Stairs[2] – stairlift
- Getting in and out of cars and buses[1]
- Toileting & bathing[2]
- In bed – e.g., sleeping, blinds, lights
- Shopping and carrying groceries[1,2]
- Cooking and domestic tasks[3]
- Beach and other uneven surfaces

1. Karmarkar, A.M., et al. (2009). Prosthesis and wheelchair use in veterans with lower-limb amputation. *Journal of Rehabilitation Research & Development, 46*(5), 567-576.
2. Ebrahimzadeh, M.H., et al. (2016). Evaluation of disabilities and activities of daily living of war-related bilateral lower extremity amputees. *Prosthetics & Orthotics International, 40*(1), 51-57.
3. Spiliotopoulou, G., & Atwal, A. (2012). Is occupational therapy practice for older adults with lower limb amputations evidence-based? *Prosthetics & Orthotics International, 36*(1), 7-14.

Falls

Falls are common and injurious for lower limb prosthetic users [1]



1. Hunter, S.W., et al. (2017). Risk factors for falls in people with lower limb amputation: a systematic review. *Physical Medicine & Rehabilitation, 9,* 170-180.
2. Kim, J. et al. (2019). Frequency and circumstances of falls reported by ambulatory unilateral lower limb prosthesis users: a secondary analysis. *Physical Medicine & Rehabilitation, 11*, 344-353.

Falls prevention & response Assistive Technologies & Home Modifications (ATHM)

Pendant[1]	Smart watch[2]	Video monitor[3]	Hearing aid[1]
Sensitivity 83%	Sensitivity 77%	Sensitivity 94%	Sensitivity 92%
Specificity 99%	Specificity 99%	Specificity 92%	Specificity 98%

1. Burwinkel, J.R., Xu, B., & Crukley, J. (2020). Preliminary examination of the accuracy of a fall detection device embedded into hearing instruments. *Journal of the American Academy of Audiology, 31*(6), 393-403.
2. Brew, B., Faux, S.G., & Blanchard, E. (2022). Effectiveness of a smartwatch app in detecting induced falls: observational study. *JMIR Formative Research, 6*(3), e30121.
3. Sangeetha, P., et al. (2021). Review of fall detection and alert systems for elderly people. *International Journal of Engineering Research & Technology, 10*(5), 667-670.

Ramps and slopes

Persons with transfemoral amputation have significantly restricted prosthetic knee flexion when walking at 5% / 1:20 [1]

Persons with transtibial amputation experiencing excessive loading that may put them at risk of OA when walking downhill at 7° / 1:8 [3]

Persons with transfemoral amputation experience 40% more loading of the contralateral limb when walking at 12% / 1:8 [2]

1. Vrieling, A.G., et al. (2008). Uphill and downhill walking in unilateral lower limb amputees. *Gait & Posture*, 28(2), 235-42.
2. Bonnet, X., et al. (2021). Distribution of joint work during walking on slopes among persons with transfemoral amputation. *Journal of Biomechanics, 129*, 110843.
3. Doyle, S.S., et al. (2019). The effect of surface inclination and limb on knee loading measures in transtibial prosthetic users. *Journal of Neuroengineering & Rehabilitation, 16*, 37.

Change in level considerations for ATHM

Image from: i-Carpentry

Vehicle AT – transfers and vehicle modifications

Handybar

Car access strap

Scooter carrier

Limbs for Life:
Vehicle modifications for Amputees

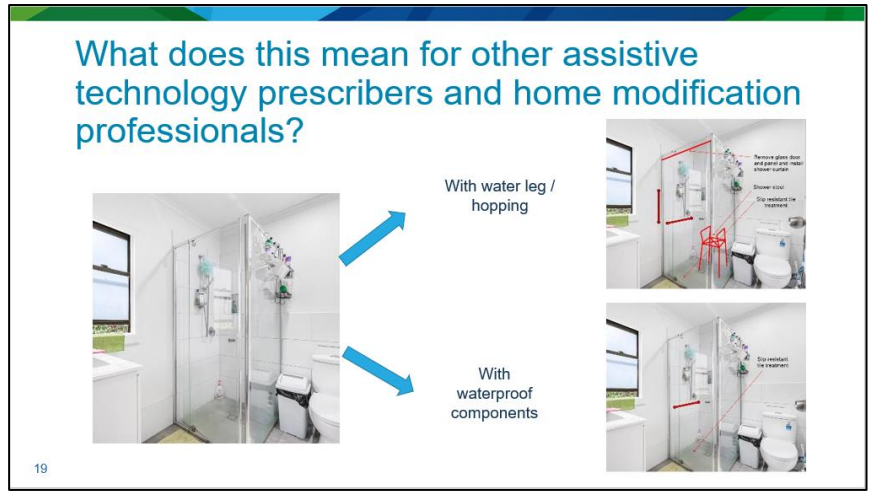
Images from: 1) Bextera Health 2) Pelican manufacturing 3) MobilityWorks

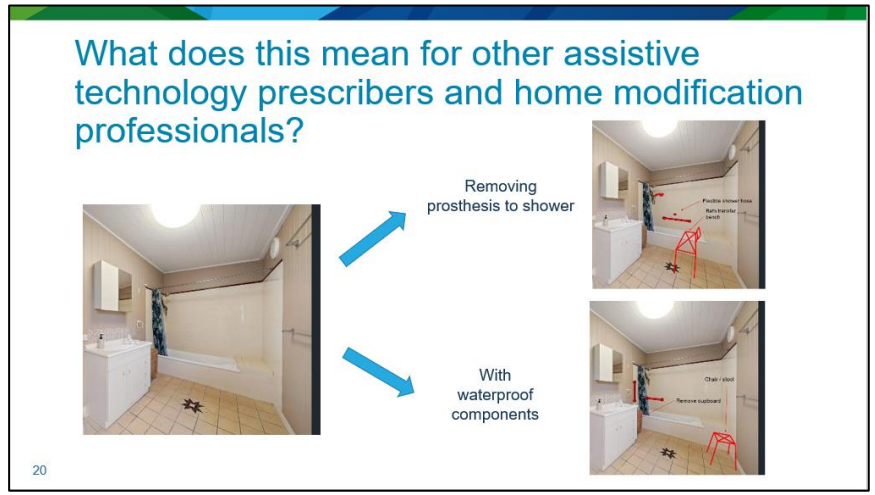
Bathroom and toilet AT

Image: Wooden Plank by FranoW, OTS and [illegible] by TapvigoEDU

Waterproof componentry

QALS updates: recording / ppt





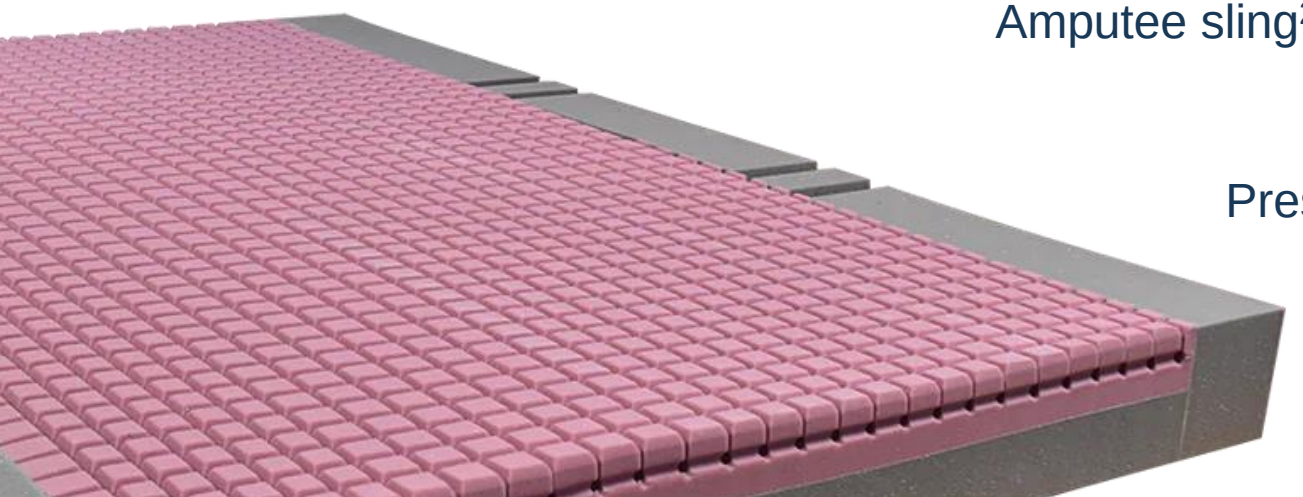
AT in the bedroom

Don’t forget to address psychosocial health, phantom limb pain, and restless leg syndrome

Amputee sling[2]

Transfer equipment[4]

Air conditioning[5] for multilimb amputees



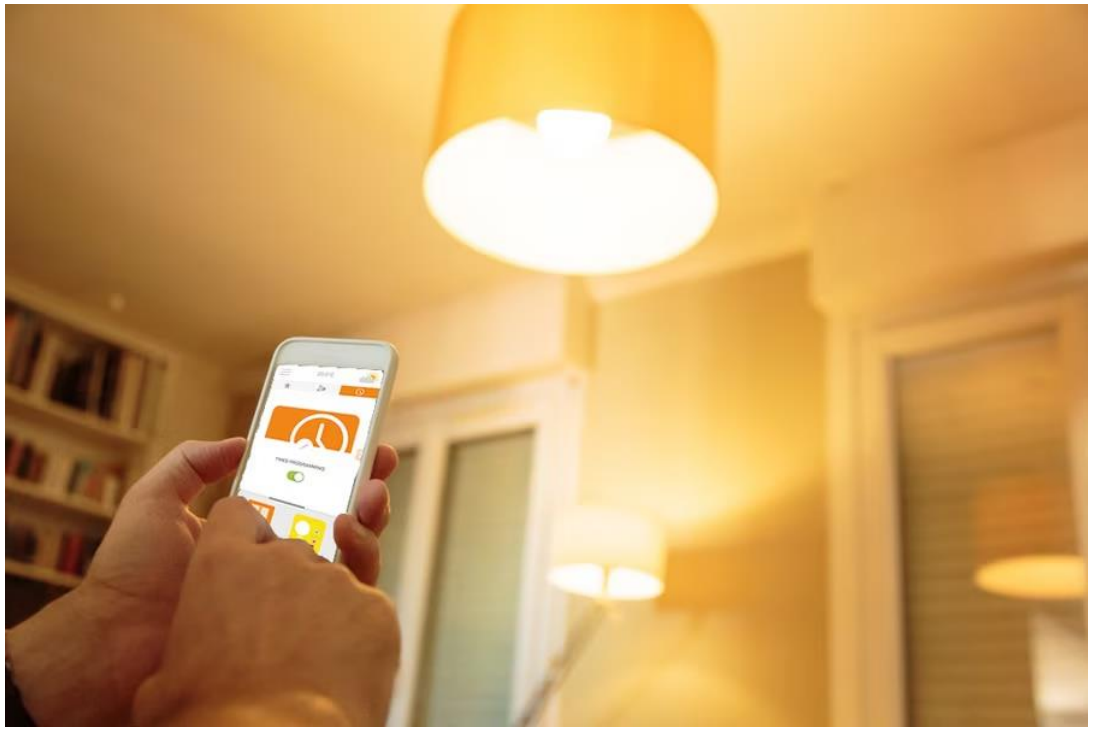
Pressure mattress[3]

Prone pillow[1]

Images from: 1) Mobi Assist, 2) Medimart, 3) Aesthetics Healthcare, 4) Active Mobility, 5) Appliances online

Home automation (e.g., from bed)

Smart blinds[1] and curtain robots[2]

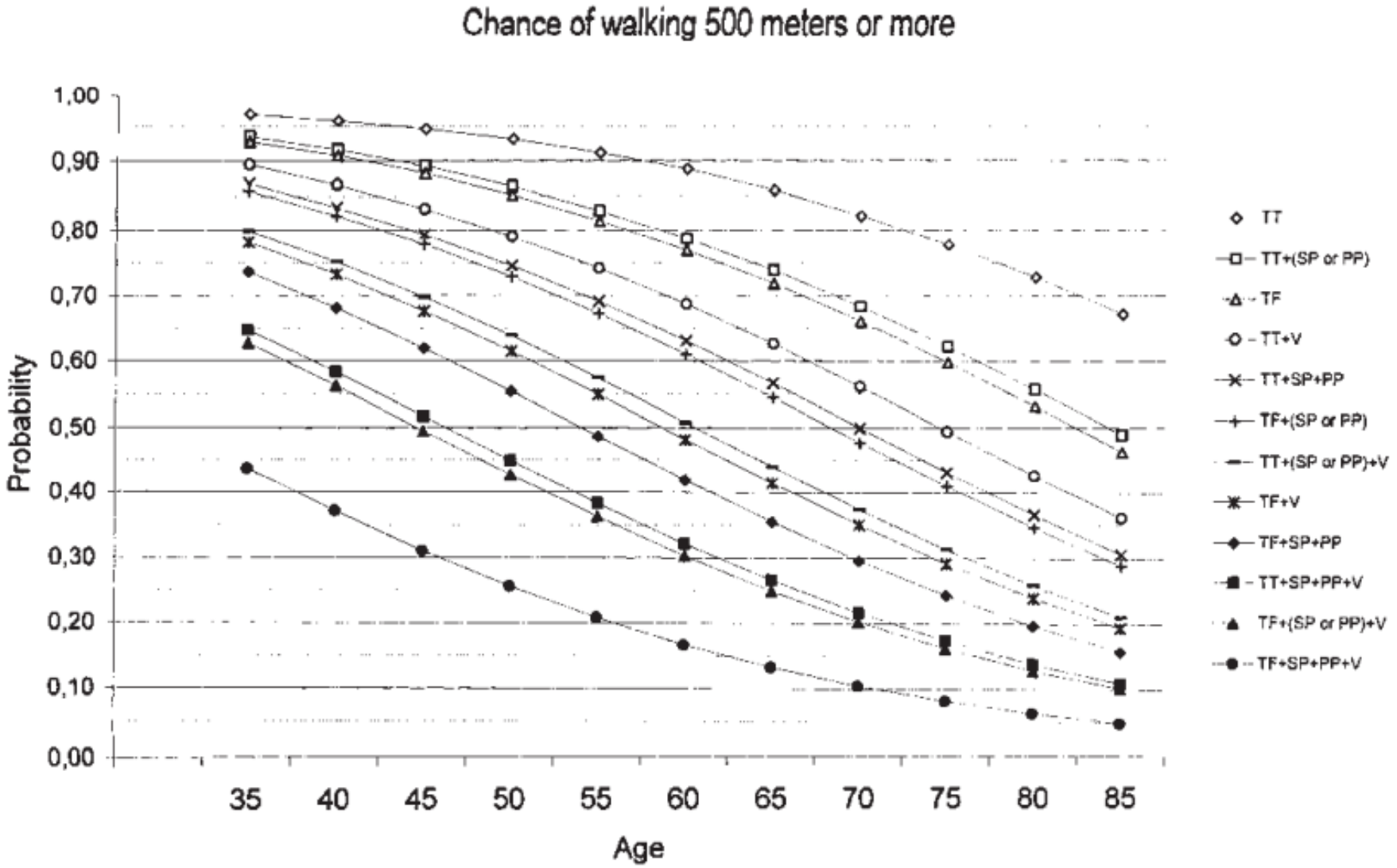


Smart lights[3]

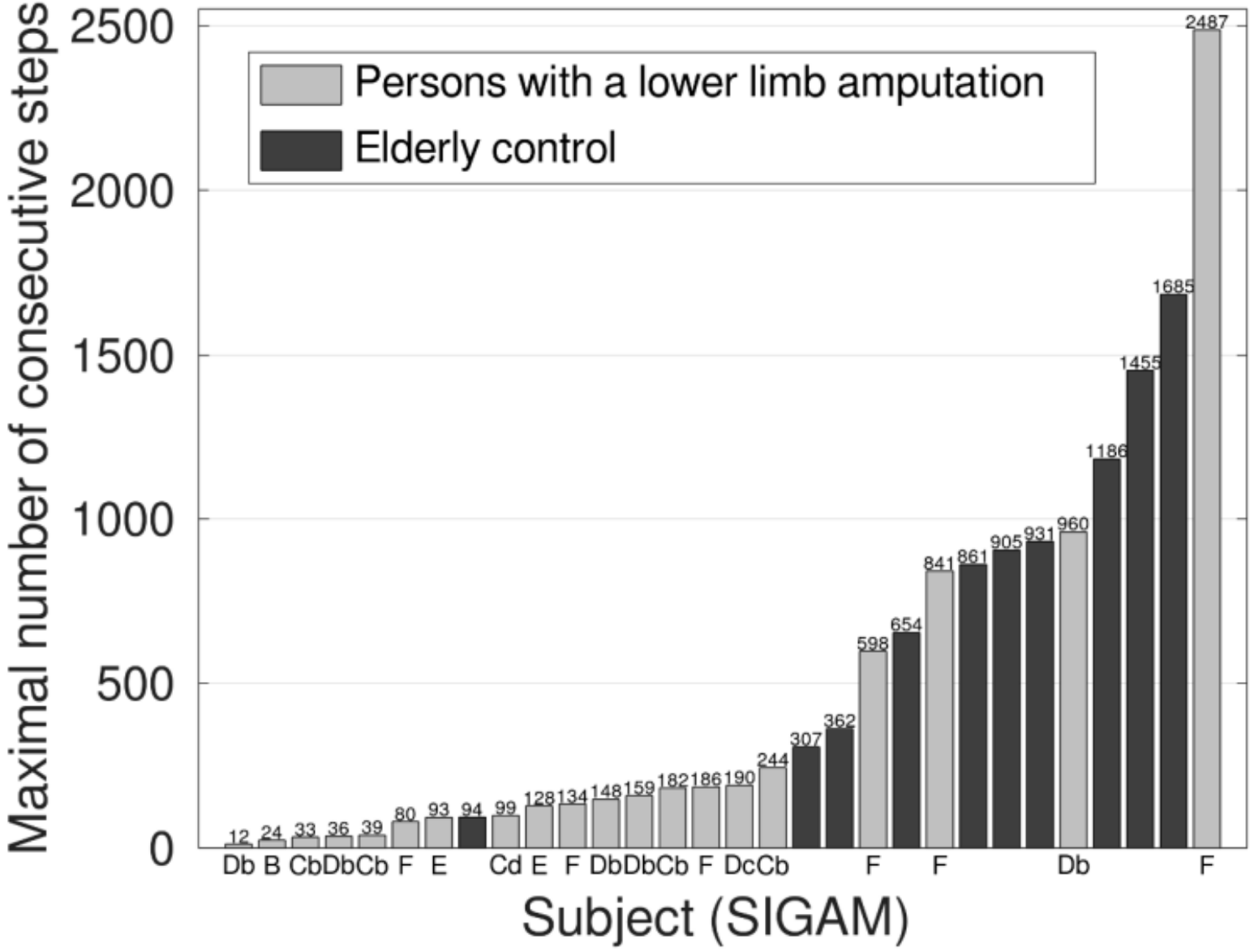
Images from: 1) Smart Blinds, 2) Switchbot, 3) Somfy

Survey study

TT: Transtibial
TF: Transfemoral
SP: Stump pain
PP: Phantom pain
V: Dysvascular



Geertzen, J.H.B., et al. (2005). Claimed walking distances of lower limb amputees. *Disability & Rehabilitation, 27*(3), 101-104.



Accelerometer study with age-matched controls

Ages: Median 68, IQR 60-74

B: Transfers only
Cb: Level ground with aids
Cd: Level ground without aids
Db: Outdoors level ground with 2 crutches or sticks
Dc: Outdoors level ground with 1 crutch or stick
E: Avoids adverse terrain or weather
F: Normal of near normal gait

Hofstad, C.J., et al. (2020). Maximal walking distance in persons with a lower limb amputation. *Sensors, 20*, e6770.

Shopping AT

Images from: Bag from Howards Storage Word, PWC from Mobility Caring, 4WW from Restora Health

Amputee Life TV

Leisure AT

Images: 1) LuAnn Kleemeyer (Abled Amputees of America, 2) Adam Galeki (Positive Bones), 3) Suncoast Spinners Wheelchair Basketball

Questions & Feedback

Complete the feedback form by scanning the QR code above or following this link. You will receive a certificate of completion after completing the form.

MASS-Education@health.qld.gov.au