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WHITE PAPER

Patient Handling – Facilitating effective Sit-to-Stand utilising hoists

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INTRODUCTION

Health Conditions increase the risk of mobility challenges in older people. These challenges are often a manifestation of decline in physical functioning and are predictive of disability progression [1].

Such mobility challenges result in negative health outcomes and a cascade of deterioration [2] such as reduced functional capacity to perform activities of daily living [3] and increased burden of care for family members and health systems [4].

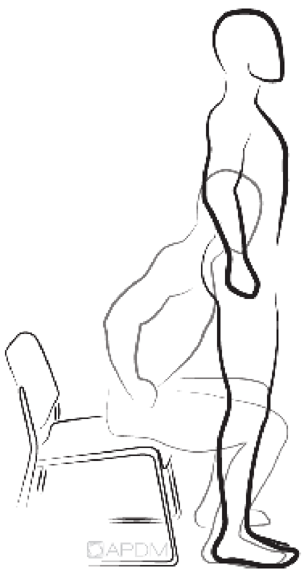
The sit-to-stand (STS) motion is a transition movement [5] and one of the most frequently performed movements by humans [6]. Rising from and sitting down in a chair is a demanding task, as it requires high levels of knee joint torques, substantial joint movement, inter-joint coordination, and balance [7].

Difficulty with the STS motion is common among elderly people, effecting more than 6 percent of community-dwelling older adults [8] and over 60 percent of nursing home residents [9]. STS is considered the most mechanically demanding functional task undertaken during daily activities [10, 11].

A decline in capacity may result in the inability to stand up, which is an important movement for performing activities of daily living. When this can no longer be performed independently, then in-home care or moving to a care facility is required [12].

While powered lift devices, Hoists, are frequently used, concern exists among Rehabilitation Professionals that habitual use of lifts may contribute to accelerated muscular degeneration due to muscle disuse [11].

It is, therefore, important to better understand the biomechanics of the STS process in order to design improved devices that can achieve appropriate trade-offs between the functional goal of enabling users to stand safely and the long-term therapeutic goal of maintaining and building muscular strength [11].



BIOMECHANICS

The STS movement can be analysed by consideration of four separate phases of the motion [12]. (Figure 1)

Phase 1 - Flexion-momentum phase: begins with initiation of the movement and ends just before the buttocks leave the chair. The head-arms-trunk segments are the main contributors to the body's forward propulsion prior to lift off during STS [12].

Phase 2 - Momentum-transfer phase: begins as the vertical motion commences in contribution alongside the progressive completion of the horizontal motion. The buttocks are lifted from the seat of the chair and ends when maximum ankle dorsiflexion is achieved [12].

Phase 3 - Extension phase: initiates just after maximal ankle dorsiflexion and is completed when the hip first ceases to extend. The vertical movement contributes increasingly during this phase [12].

Phase 4 - Stabilisation phase: begins just after the hip-extension concludes and continues until all stabilising motions are completed [12].

STS requires an initial movement impulse in the horizontal direction, adding increasing movement in the vertical direction. The horizontal distance moved by the centre of body mass (COM) and the timing of lower limb extensor force in relation to the position of the COM are critical to ensure both a change in direction occurs and preservation of equilibrium over the feet [13].

One of the key features of an effective STS is the ability for the COM to come over the Base of Support (BOS). Only then will the body achieve the alignment of the two in order to effectively achieve the commencing vertical component of Phase 2 of the movement, but also to retain balance for the remainder of the motion.

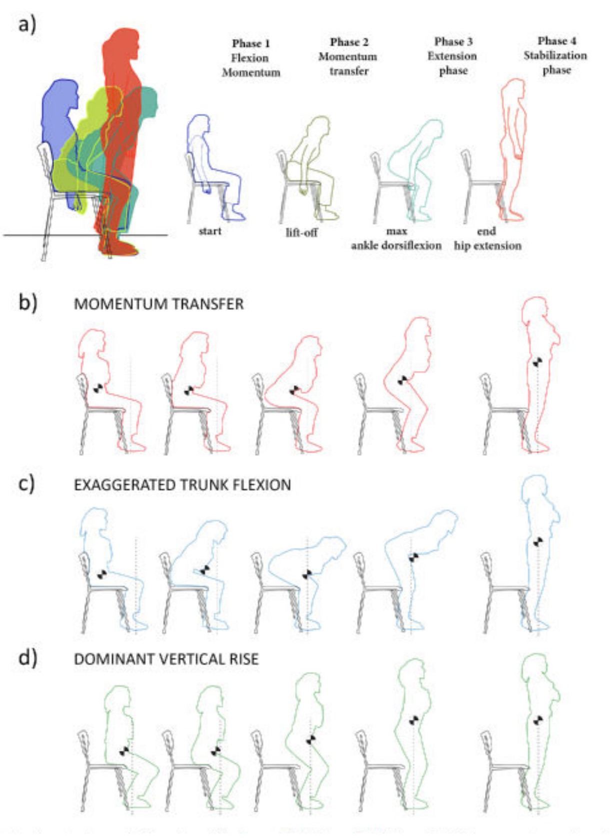


Figure 1: Four Phases of STS [12].

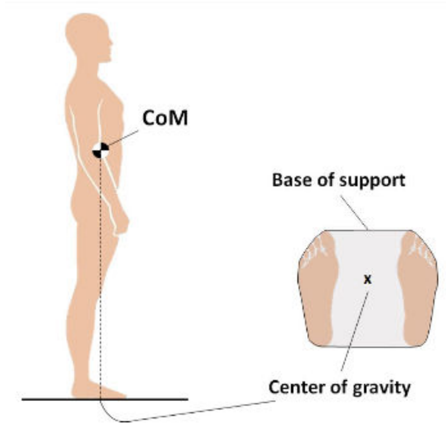


Figure 2: CoM and BoS in standing

The COM (Figure 2) refers to It is the average position of all the parts of the system, weighted according to their masses. A reference point for the mean location of the weight of the body.

The BOS (Figure 2) refers to the area beneath an object or person that includes every point of contact that the person makes with the supporting surface.

In a STS the BOS shifts from chair and feet combined, to complete feet weight bearing (Figure 3). Therefore we need to move the COM appropriately to prepare for full contribution of the feet. In the STS the transfer of COM off the chair shifting BOS on the feet alone is critical to achieving successful STS.

Getting the COM over the feet (Figure 3) is achieved by tipping the trunk horizontally by hip flexion, knee flexion and ankle dorsiflexion. Known as triple flexion. The closer the feet are to the chair the less the trunk needs to flex to get the COM above the feet. This motion is performed with horizontal momentum [14].

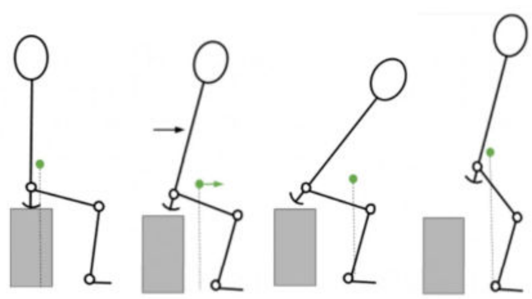


Figure 3: CoM moving over BoS in STS [14]

COMPENSATORY FACTORS

For those unable to achieve STS some adaptations are able to be made, deviating from the standard STS motion, to allow STS to occur under different conditions.

Compensatory STS movements (Figure 1) can be adopted when the biomechanics of a normal STS are no longer able to be achieved. This results in the same functional outcome albeit joint angles can be exaggerated or decreased to offset changes in strength, range of motion, momentum, coordination, asymmetry and balance.

In compensatory STS (Figure 1) the horizontal location of the COM over the BOS at the time of take-off, and the magnitude and timing of the peak horizontal momentum of the COM remain similar to a normal STS [15] as these are essential components of success. These two factors are necessary conditions for maintaining upright stance at the termination of dynamic weight transfer [15].

Additional factors can also affect STS success in those unsuccessful with normal STS. Chair seat height and use of armrests, have a major influence on the ability to do an STS movement [16].

The height of a chair seat effects the burden on the lower limbs during the STS [17]. An example height raise would be 20% of lower limb length [17]. With an increase in chair height, there is reduced need for strength, decreased requirement for momentum [17] and decreased need for foot repositioning [16].

Armrests have been found to support STS performance by assisting stability and increasing confidence and autonomy [18]. Using the armrests lowered the motion at the hip by 50%, without influencing the range of motion of the other joints [16]. Armrest position around 250mm from the seat best facilitate STS performance [18]

TRAJECTORY OF STANDING

By mapping joint positions and angles during a STS we are better able to visualise the trajectory of the movement.

Figure 4 depicts a representative movement pattern at 21 points in the STS movement. It additionally depicts the trajectory at data points at the tragus, acromion, midilliac crest, hip and knee [19]. It is notable that the effective trajectory of both hip and pelvic measures indicates a reasonably linear diagonal path from seated to standing.

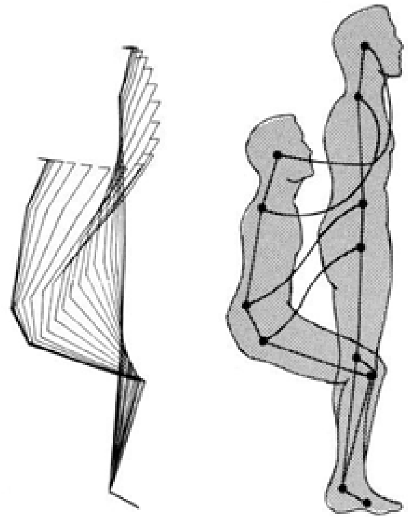


Figure 4: Trajectory of body in STS [19]

This same directional representation can be seen when mapping the trajectory of the COM during STS. Figure 5 notes the phases of STS, where the path of the COM in Phase 2 and 3 of the movement demonstrates a similar linear diagonal trajectory [20].

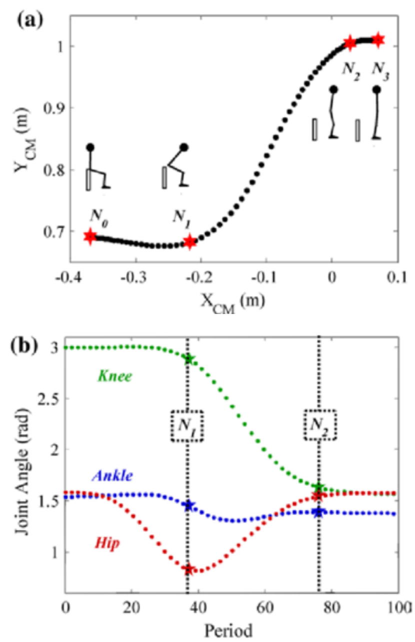


Figure 5: Trajectory of CoM in STS [20]

When compensatory or assisted STS is mapped (Figure 6), a similar trajectory is seen as when unassisted or assisted in STS. The movement of the COM follows the linear diagonal path from sitting to standing. This includes assistance using push up from the seat, carer waist assistance, carer arm assistance and use of an assistance bar [11].

The overwhelming similarity of movement trajectory when active STS performed, compensatory, assisted and unassisted, provides information on the requirements of movement to achieve an effective, active STS. This trajectory allows utilisation of strength and momentum most natural for all forms of STS.
Figure 5 highlights the angle changes and required joint movement during the STS.

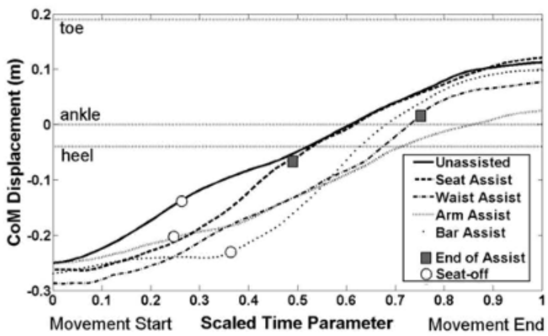


Figure 6: Trajectory of CoM in varied STS conditions [11]

The ankle experiences dorsiflexion in Phase 1, followed by plantarflexion in Phase 2 to achieve the extension and stability at the ankle for standing.

The knee commences in a flexed position in Phase 1 in preparation bringing the BOS closer to the COM. Following this progressive extension occurs at a constant rate until the end of Phase 3.

Figure 7: Examples of manual assistance by a caregiver in STS

The hip experiences the most change in angle and is indicative of the high levels of muscle coordination to complete the STS. The hip has a fast and significant movement into flexion during Phase 2, followed by extension as the horizonal component of the motion commences.

INCREASED PARTICIPATION

Physical activity can improve or maintain mobility in older people by enhancing their overall physical function [28]. Older people with mobility challenges benefit from interventions involving muscular strength, flexibility and balance, such as the sit-to-stand activity [1].

In older patients, hospitalisation is associated with a decline in functional performance and loss of muscle strength. This can be prevented by systematic strength training [21].

STS training could be a useful intervention when patients have limited STS function and the aim of treatment is to improve this performance [22]. Rehearsing the skill leads to improvement in functional achievement.

The repetition of the STS activity is frequently completed in the context of daily living. It is a simple activity, which does not require specialist training to facilitate. It is a relevant, affordable and effective intervention to improve or maintain mobility in older people. It is a means of improving STS performance, optimising mobility and function [1].

The repetitive STS activity can improve mobility related functions such as STS itself, activities of daily living and balance, benefiting older people with and existing functional deficit [1].

On average, healthy adults perform approximately 60 (±20) STS motions every day. However, completing only 11-13.5 STS activities a day, stroke patients increased their ability to stand up safely and consistently [1].

In a Hospital setting intervening immobile patients with Hoist assisted standing, in addition to their early Rehabilitation program, achieved earlier mobilisation, shorter hospitalisation and easier return to daily life activities [23]. Enabling patients to stand on their feet and to be mobilised in the early period, using a Hoist, accelerates the recovery of systemic functions and allows the patient with neurological diseases to improve towards independence [23].

ASSISTIVE TECHNOLOGY

An STS assistive device, or Hoist, is a piece of automated medical equipment that can facilitate Rehabilitation training for patients with lower limb disorders and improve their lower limb function [24]. Use of a Hoist to assist STS occurs in Community, Aged Care and Acute Care environments.

A STS Hoist is not only designed to replace manual lifting of people during a transfer (Figure 7), keeping caregivers safe, but also to maximise activity and participation of the person. It can also be referred to as an ‘active lifter’.

The ability for a person to be active in cooperation depends on the coordination between the device, joint angles and trajectory. If the person and Hoist cooperation is out of synchronisation, it will inevitably cause harm to patients with lower limb disorders [24]. Improvement in this cooperation of Hoists has become an important standard of design quality [24].

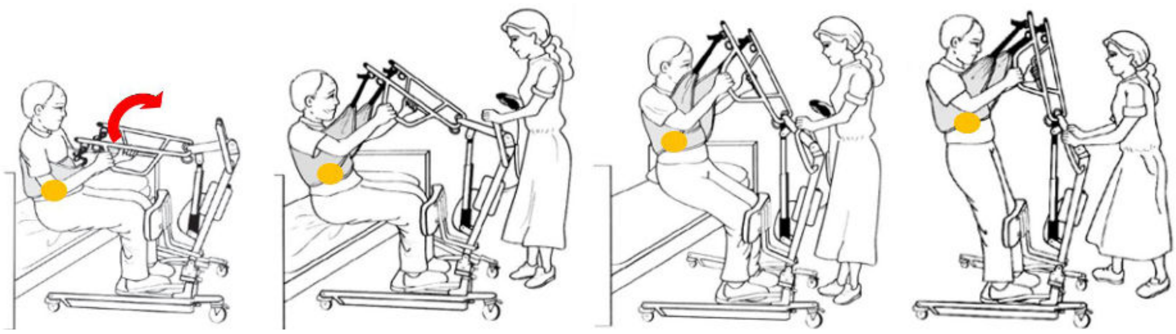


Figure 8: Mechanism for a standard, traditional STS Hoist with CoM [25]

The parameters of trajectory, velocity of joints, and plantar pressure, needs to be of high consideration in design [24].

Hoist designs to improve the cooperation of the person will more markedly allow for mimicking of the BOS over the COM and the trajectory of the hips in achieving an assisted STS. This will result in effective repetitive practice of the STS action, enabling the rehabilitative benefits of this activity.

This effectively alters the purpose of the Hoist in that whilst a transfer is occurring, active Rehabilitation can occur. A limitation to achieving these goals exists in the mechanical design of standard, traditional Hoists that assist STS. The arc of movement that the traditional Hoist dictates is contrary to the biomechanics of normal STS. (Figure 8) The arc consists of a strong vertical component of movement followed by horizontal movement. This is opposite to natural biomechanics and means the person is unable to activate standard patterns of muscle activation, joint angulation and coordinated momentum.

The Hoist uses the knees as a fulcrum to lever the body from the sitting position to standing, this can be taxing on this joint. In addition, the COM is held far behind the BOS until the final stage of the Hoist motion, and if the person is not taken to complete standing, it will not occur at all. (Figure 8)

For a traditional Hoist the sling attaches to the lifting arm at one single point. This point of the Hoist is the driver of the assistance supplied and the angle in which support of the person occurs. With correct sling placement at the commencement of the motion, weakness by the person, or lack of engaged activity, will allow the sling to rise in line with the vertical direction of Hoist pull.

As progression to standing occurs, if the sling moves up, the force of the sling on the person's axilla will compress critical nerves and blood vessels and increase levels of discomfort/pain. (Figure 9) This may prevent achievement of full standing, minimising the advantages of the Hoist's intended active use to achieve standing.

Alternative Hoist designs have been introduced, that deviate from the standard mechanism, with the ambition of improving the correlation of the Hoist assistance to facilitate normal STS motion.

One example is the Molift Quick Raiser 205 (Figure 10). Designed with biomechanics in mind, this Hoist achieves the same effective transfer as a standard Hoist, though utilises direction of movement to benefit the person's ability to rehearse movement more similar to a standard STS.

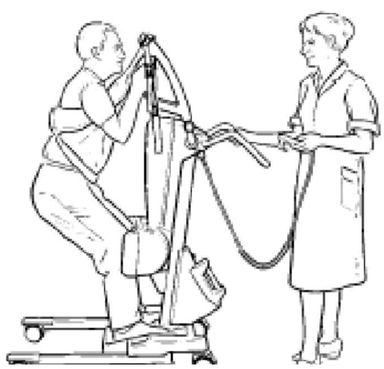


Figure 9: Orientation sling under axilla

Figure 10: Molift Quick Raiser 205

The diagonal orientation of the lift column allows the lift arm to move in a linear diagonal motion rather than a pivot action around a single point. (Figure 11)

The major design differences are the diagonal orientation of the Hoist lifting column, the linear diagonal movement of the lifting arm and the 4 point sling attachment.

This design is intended to allow the assistance the Hoist supplies to facilitate a more natural STS motion, in line with the linear diagonal motion of the hip, pelvis and COM in normal STS. (Figure 11). This gives potential for muscle activation and coordination of movement to follow more effectively the desired normal STS.
The design of the 4 point sling attachment (Figure 12) means that the direction of pull is not limited to one single point vertically orientated.

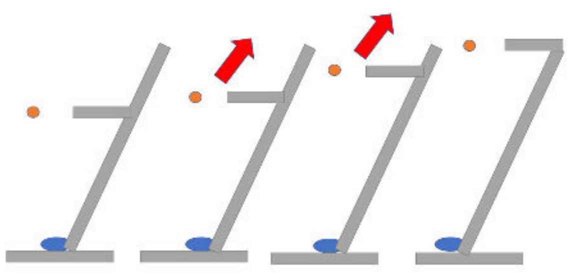


Figure 11: Diagonal orientation of lift column and lift arm movement relative to BoS and CoM

The sling is supported equally superiorly and inferiorly, maximising the surface area the person has in contact with the sling, thus decreasing lines of increased peak pressures of the skin and tissue. This makes the transfer more comfortable and offers greater effective assistance.

Ensuring the sling supports the motion at the hip and pelvis is essential to achieve the desired movement pattern. Keeping the sling positioned on the lower back and minimising riding up under the arms is critical in allowing COM to come over BOS, protecting the axilla and minimising discomfort to achieve full standing. This is achieved through uniform contact at the top and base of the sling.

The 4 point attachment changes the orientation of the 'pull' to a greater horizontal force mimicking the hip flexion during Phase 1 and supporting the increasing vertical motion associated with hip extension.

FOCUS ON REHABILITATION

The World Health Organisation estimates that there will be two billion people over the age of 60 in the world by 2050. Whilst by 2035 we will be short of 12.9 million healthcare professionals [26].

The need to provide Rehabilitation to people in care at home and in institutions is of increasing importance. That is, the maintenance of current functional levels, or rehabilitative improvements.

There is opportunity to improve the rehabilitative effort utilising standard transfers, that are already occurring multiple times every day, in line with quality care and performance of activities of daily living. By maximising active input from the person during transfers we are able utilise the Hoist as part of the Rehabilitation process. This means activities are not reserved to Therapy sessions but can be complemented by regular active movement in the process of standard care.
Facilitating the most effective STS using a Hoist will allow for rehearsal of components of the STS with as much respect to normal STS as possible. This requires the Hoist to assist and allow COM to come as close to BOS as safely possible, for momentum to be maintained, and for the trajectory of the hip and COM to be facilitated in the linear diagonal path of normal STS.

This encourages a more effective, active participation whilst using the Hoist to facilitate practice of STS. Allowing the volume of repetitions to increase will facilitate the rehabilitative effect and impact improving STS performance, optimising mobility and function [1].

It requires Therapist and carer perception of the Hoist to change, it isn't just a transfer tool, but a piece of Assistive Technology that maximally benefits the person from a rehabilitative perspective. It also requires us to actively engage the person in the movement, extending their active participation with the support of the Hoist.

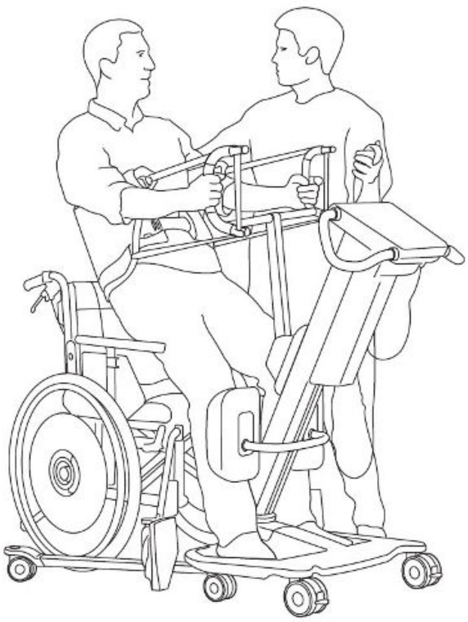


Figure 12: 4 point sling attachment

SUMMARY

The STS movement is an important functional activity that can be challenging for older adults or those with changes in neuromotor control [27]. The STS movement is a skill that helps determine the functional level of a person [16].

While STS Hoists are frequently used in transferring of people, it is important to better understand the biomechanics of the STS process [11] in order to appreciate the design differences between the array of Hoists available in the market.

Improved Hoist designs can achieve appropriate facilitation of achieving the functional goal of enabling users to stand safely and the long-term therapeutic goal of maintaining and building muscular strength [11]. Thus, should be explored as an alternative to the traditional Hoist.

Hoists, such as the Molift Quick Raiser 205, are designed biomechanically to align with standard hip and COM trajectory, assisting in a more normal functional STS movement. This may be of benefit in increasing repetition of STS activity and contributing positively to a holistic goal orientated rehabilitation program.

Increasing participation in an active assisted STS can benefit those with mobility challenges. The benefit from interventions involving muscular strength, flexibility and balance such as the STS activity [1] has a strong correlation to improvement in STS performance, optimising mobility and function [1]. Thus the STS is a movement that should be actively encouraged and facilitated by Hoist design.

REFERENCES

1. Duarte Wisnesky U, Olson J, Paul P, Dahlke S, Slaughter SE, de Figueiredo Lopes V. Sit-to-stand activity to improve mobility in older people: A scoping review. Int J Older People Nurs. 2020 Sep. 15(3)
2. Satariano, Guralnik, Jackson, Marottoli, Phelan & Prohaska. Mobility and Aging: New Directions for Public Health Action. American Journal of Public Health. 2012. 102(8):1508-1515
3. Albert, Bear-Lehman & Anderson. Declines in Mobility and changes in performance in the instrumental activities of daily living among mildly disabled community-dwelling older adults. Journal or Gerontology Series A. 2015. 1:71
4. Mooyeon, O. Interplay between cognition and mobility in older adults. Annals of Geriatric Med. And Res. 2017 1:2
5. Bohannon, RW. Daily sit-to-stands performed by adults: a systematic review. 2008. 27(3): 939-942
6. Galli, Cimolin, Crivellini, Campanini. Qualitative analysis of sit to stand movement: Experimental set up definition and application to healthy and hemiplegic adults. 2008. 28(1):80-85
7. Wenxia X, Yu B, Cheng L, Li Y, Cao X. Multi-fuzzy Sarsa learning-based sit-to-stand motion control for walking-support assistive robot. International Journal of Advanced Robotic Systems. 2021. 18(5).
Leon T, Lair J; National Medical Expenditure Survey. Functional status of the noninstitutionalized elderly: Estimates of ADL and IADL difficulties. Rockville (MD): U.S. Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research; 199
8. Leon T, Lair J; National Medical Expenditure Survey. Functional status of the noninstitutionalized elderly: Estimates of ADL and IADL difficulties. Rockville (MD): U.S. Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research; 199
9. Mehr DR, Fries BE, Williams BC. How different are VA nursing home residents? J Am Geriatr Soc. 1993. 41(10): 1095-1101.
10. Riley PO, Schenkman ML, Mann RW, Hodge WA. Mechanics of a constrained chair-rise. J Biomech. 1991. 24(1):77–85.
11. Jeyasurya, J, Van der Loos, M, Hodgson, A, Croft, Comparison of seat, waist, and arm sit-to-stand assistance modalities in elderly population, JRRD. 2013. 50(6):835 - 844
12. Van der Kruk, E, Silverman, AK, Reilly, P, Bull, AMJ. Compensation due to age-related decline in sit-to-stand and sit-to-walk, Journal of Biomechanics. 2021. 122
13. Carr, J. Balancing the Centre of Body Mass During Standing Up, Physiotherapy Theory and Practice, 1992. 8(3):159-164
14. Johnson, P. The Physics of Sit-to-Stand. Biomechanics. August 5, 2019
15. Pai, Y-C, Naughton, BJ, Chang, RW, Rogers, MW. Control of body centre of mass momentum during sit-to-stand among young and elderly adults, Gait & Posture. 1994. 2(2): 109-116
16. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: a review. Phys Ther. 2002. 82(9):866-79
17. Demura S, Yamada T. Height of chair seat and movement characteristics in sit-to-stand by young and elderly adults. Percept Mot Skills. 2007. 104(1):21-31
18. Blackler, A, Brophy, C, O'Reilly, M, Chamorro-Koc, M. Seating in aged care: Physical fit, independence and comfort. SAGE Open Medicine. 2018. 6:1–17
19. Nusic. Biomechanics. Unknown
20. Sadeghi, M., Emadi Andani, M., Bahrami, F. et al. Trajectory of human movement during sit to stand: a new modelling approach based on movement decomposition and multi-phase cost function. Exp Brain Res. 2013. 229:221–234
21. Pedersen MM, Petersen J, Bean JF, Damkjaer L, Juul-Larsen HG, Andersen O, Beyer N, Bandholm T. Feasibility of progressive sit-to-stand training among older hospitalized patients. PeerJ. 2015. 17(3)
22. Chaovalit S, Taylor NF, Dodd KJ. Sit-to-stand exercise programs improve sit-to-stand performance in people with physical impairments due to health conditions: a systematic review and meta-analysis. Disabil Rehabil. 2020. 42(9):1202-1211.
23. Duymaz T, Ozgonenel L, Iyigun ZE. The efficacy of the electric patient Hoist systems in mobilization. North Clin Istanb. 2019. 6(4):361-367.
24. Zhoua,B, Xue Q, Yanga,S, Zhanga,H and Wanga,T. Design and control of a sit-to-stand assistive device based on analysis of kinematics and dynamics. AUTOMATIKA. 2021. 62(3–4):353–364
25. PROTEKT® 500 STAND SIT-TO-STAND PATIENT LIFT MODEL: 34500. User Manual
26. Linak, Support Rehabilitation efforts with reliable sit-to-stand lifts. 2018
27. Jeon W, Whitall J, Griffin L, Westlake KP. Trunk kinematics and muscle activation patterns during stand-to-sit movement and the relationship with postural stability in aging. Gait Posture. 2021. 86:292-298.
28. Stathi, McKenna & Fox. Processes associated with participation and adherence to a 12-month exercise program for adults aged 70 and older. Journal of Health Psychology. 2015. 15(6):838-847

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