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TREADMILL TRAINING AFTER STROKE

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LEARNING OBJECTIVES

By the end of this chapter, you will be able to:

- Define treadmill training with and without body weight support
- Describe different populations for whom treadmill training is appropriate
- Outline the rationale for treadmill training
- Give an overview of the evidence for treadmill training
- Outline how to apply treadmill training with and without body weight support

INTRODUCTION

Being able to walk is a major determinant of whether a patient returns home after stroke. The cost of being unable to walk is high, usually involving a lifetime of residential care. Furthermore, being able to walk well is integral to people's ability to participate in their community. Even amongst stroke survivors who undergo rehabilitation programs, only 7% are able to walk effectively when they return home (Hill et al 1997). This has serious repercussions for their quality of life – they are likely to become housebound, socially isolated, and dependent on others for their basic needs.

Treadmill training, with or without body weight support (BWS), is a relatively new intervention designed to train walking. It has the potential to reduce disability after stroke by improving walking thereby reducing the burden on the community. Importantly, it is also highly practicable, because treadmills are widely available. However, treadmill walking is biomechanically different to overground walking (Van Ingen Schenau 1980). Less well understood is whether these differences are important for recovery of walking after stroke. Hesse (2008) reported that some clinicians are still reluctant to use treadmill training as an intervention after stroke for fear patients would practice abnormal walking patterns. Therefore treadmill training not only needs to be proven to be effective in terms of amount and capacity of walking, but it also needs to be shown not to be deleterious in terms of quality of walking. This would then remove potential barriers to widespread implementation of the intervention in stroke rehabilitation.

This chapter will cover the use of the treadmill to (i) increase the number of people who can walk after stroke as well as (ii) to attain a level of walking ability commensurate with community living. In each of these two situations, the rationale for using the treadmill as well as the evidence will be presented, followed by information on how to use the treadmill to best effect.

USING TREADMILL TRAINING WITH BODY WEIGHT SUPPORT FOR ACUTE NON-AMBULATORY STROKE PATIENTS

Rationale for using treadmill training with BWS

Only half of the non-ambulatory stroke patients admitted to inpatient rehabilitation learn to walk again (Dean and Mackey 1992). In order to optimise the outcome of walking, practice is critical because skill in performance improves as a function of practice (Johnson 1984). For non-ambulatory stroke patients, treadmill training with partial weight support provides the opportunity to complete more walking practice than would be possible using assisted overground walking (Hesse 1998, Richards et al 1993). There is evidence from systematic reviews that outcome following stroke is associated with the amount of practice undertaken (Kwakkel et al 2004, Langhorne et al 1996). Unfortunately, little practice is completed in rehabilitation (Mackey et al 1996, Esmonde et al 1997). One of the barriers to completion of more walking practice in non-ambulatory stroke patients is marked muscle weakness and poor coordination, which results in an inability to practice the whole task. Assisting overground walking in non-ambulatory patients is labor intensive and therefore limited. Even with the assistance of two or more therapists, patients may not be able to complete more than a few steps of overground walking. Treadmill training with body weight support via an overhead harness provides the opportunity to complete larger amounts of walking practice. Hypothetically, even if patients only walk for 5 min at a slow speed of 0.2 m/s supported on a treadmill, they will 'walk' 60 m. In a recent randomised trial (Ada et al 2010), in Week 1 the average distance walked per session by the overground walking group was only 20% of the treadmill training with BWS group and in the last week the distance was still less than 50% even though the amount of time allowed to be spent on walking was the same for both groups. That is, for a similar therapy time, more walking was carried out using the treadmill.

The provision of weight support for this population seems crucial since Visintin et al (1998) found a small beneficial effect when treadmill training was combined with partial weight support compared with no weight support. Moreover, treadmill training with partial weight support via an overhead harness means that the therapist can provide large amounts of walking practice without contravening occupational health and safety standards in that therapists are less likely to injure their back and patients are less likely to fall. Furthermore, treadmill training with BWS is an efficient use of staff time. It usually takes two or more therapists to help non-ambulatory stroke patients practice the whole task of walking overground. Walking on the treadmill with BWS means that patients may only need the help of one therapist to move the affected leg forward in swing phase, even if it takes two people to assist them onto the treadmill. It is easier to move the leg during swing when in one place on a treadmill compared with supporting it during swing and stance while trying to progress overground. This is because it does not matter if the knee flexes during stance since the body is supported.

Evidence for using treadmill training with BWS

In this population of stroke patients, ie, those who are non-ambulatory early after stroke, we are interested in two outcomes. First, does treadmill training with BWS result in more independent walking, and second, is it detrimental to the quality of walking?

In terms of the amount of independent walking, efficacy of treadmill training with BWS has been examined in a Cochrane review (Moseley et al 2005) which reports that there is no greater risk of being non-ambulatory if treadmill training with BWS is used than if other physiotherapy interventions are used (RR 1.1, 95%CI 0.9 to 1.3). Since this review, two more large trials with over 120 acute stroke patients each have been completed comparing treadmill training with BWS to overground walking (Ada et al 2010, Du et al 2008). Ada and colleagues (2010) report a risk difference of 10% (95% CI -6 to 27) while Du et al (2008) report 28% (95% CI 13 to 43) in favour of treadmill training with BWS.

In terms of quality of walking, the Cochrane review found that walking speed was no different as a result of treadmill training with BWS (MD -0.01 m/s, 95%CI -0.08 to 0.06). Ada and colleagues (2010) also found no difference in walking speed (MD 0.08, 95% CI -0.07 to 0.23). In summary, it appears that treadmill training with BWS may be beneficial in producing more independent walking without detriment to the quality of walking.

How to use treadmill training with BWS

Observational studies which compare walking overground to walking on a treadmill with BWS in stroke patients who are just walking or walking with difficulty can be examined to inform us about how to apply treadmill training with BWS. One of the common findings is that by adding BWS, the symmetry of walking is improved by increasing the time the affected leg spends in single stance phase. However, there may be a limit to how much support should be given. Hesse and colleagues (1997) compared 0, 15, 30 45 and 60% BWS and found that over 30% BWS resulted in markedly abnormal muscle activity when they examined six lower limb muscles. This has resulted in a maximum of 30% BWS becoming something akin to an industry standard. Perhaps the most useful information comes from Chen and colleagues (2005a and b) who systematically varied BWS, speed of treadmill, stiffness of the support harness, and support from a handrail. They found that different factors were helpful in different aspects of walking. For example, increasing BWS combined with support from a handrail produced the most symmetrical walking in terms of time spent in single stance phase whereas increasing the speed increased the energy at toe-off. Increasing the stiffness of the support harness increased the energy cost during swing phase which may be both good and bad. Sullivan and colleagues (2002) carried out a randomised trial comparing three treadmill speeds during training with BWS for patients who could walk but walked slowly. They found that the fastest speed increased final overground walking speed by 0.13 m/s (p=0.02) more than the two slower speeds.

It makes sense to examine how treadmill training with BWS was carried out for the non-ambulatory participants in the Cochrane review (Moseley et al 2005). Training sessions varied from 20-45 min every week day. Initial BWS varied from 10-100% across trials. All report manipulating BWS and treadmill speed to progress training. However, number of therapists assisting, whether support from a handrail was allowed, whether shoes were worn, and whether the ankle was splinted were reported variably across trials. Perhaps the most helpful information of the interaction between treadmill speed and BWS comes from da Cunha Filho and colleagues (2002). They report that BWS was started at 30% and decreased until knee flexion during stance was no more than 15 deg. When normal step length could be taken consistently, the speed of the treadmill was increased incrementally, by 0.01 m/s at a time. In the two large randomised trials published recently (Ada et al 2010, Du et al 2009), the training was carried out for 30-80 min/day. In one trial (Ada et al 2010, Dean et al 2010), initial BWS was set so that the knee was within 15 degrees of extension in mid stance and initial speed of the treadmill was set so that the therapist had time to assist the leg to swing through while maintaining a reasonable step length. A reduction in BWS occurred once participants could swing the affected leg through without help; maintain a straight knee during stance phase without hyperextension; and maintain an adequate step length. Once they attained a speed of 0.4 m/s without BWS, they commenced 10 minutes of overground walking. In the other trial (Du et al 2009), initial BWS was 30-40% and average treadmill speed was 0.1-0.5m/s and then speed was increased and BWS reduced according to the individual pattern of recovery.

Tips and advice in using treadmill training with BWS

Insights into the practicalities of training non-ambulatory people after stroke have been gained through carrying out a large, multicentre randomised trial of treadmill training with BWS (Ada et al 2010, Dean et al 2010). Our experience during this trial suggests that attention should be directed to support of the patient, method of therapist assistance, and progression of training. Also, see www.physiotherapyexercises.com for exercises and text of treadmill training with non-ambulatory stroke patients.

- **Ensuring the safety of the patient.** Organise medical clearance to participate in treadmill with BWS training. If the patient has communication problems, modify safety procedures, eg, teach patient to signal that the treadmill should be stopped. Attach safety strap, have relative or aide standing by emergency stop switch. The treadmill may have to be modified so that the safety switch can be reached by the therapist helping the affected swinging leg. Make sure the patient wears shoes.
- **Getting the patient onto the treadmill with BWS.** If the patient is severely disabled, it is more efficient to apply the harness in lying, transfer them to the treadmill by wheelchair, and use the automatic lift function to lift them into standing than to put the harness on in sitting and get them to stand up themselves. Make sure that the harness used allows adequate hip extension during stance, ie, it does not have straps that run across the gluteal fold.
- **Supporting the affected arm.** If the affected arm has no voluntary muscle activity, use a firm sling to support it but if there is some activity, put the hand on the handrail and secure it using a bandage or a weightlifting splint (Figure 1).
- **Assisting the swinging leg**. The most difficult job for the therapist is to lift the affected leg through during swing phase (Figure 2). A splint can be attached to the foot (Figure 2a) or the front most shoelace can be loosened to provide a loop. Alternatively, the affected foot can be placed in a pillow slip and twisted at the front (Figure 2b) so that the foot can be lifted from the toe, thereby encouraging dorsiflexion of the ankle. When the leg is very weak, a length of theraband can be tied from the front of the shoe to the front bar of the treadmill which will serve to pull the leg forward when the weight is released (Figure 2c). In this situation, the foot has to be held onto the treadmill during stance phase.
- **Ensuring the safety of the therapist.** The therapist can sit on a chair turned backwards which will support the trunk making lifting the affected leg easier. The chair may have to be modified depending on the height of the treadmill (Figure 3).
- **Starting to walk on the treadmill.** To begin with, do not run the treadmill. Increase BWS so that the knee of affected leg is bent no more than 15 degrees. Turn on a metronome at a frequency which matches the highest cadence that the patient can

manage. Help the patient to walk on the spot in time with the rhythm by using one hand to flex the knee and the other hand to lift the foot of the affected leg. Then turn the treadmill on as slowly as possible and get the patient to keep 'stepping' in time with the metronome – the metronome frequency and the treadmill speed will determine step length. Lift the affected leg forward during swing phase but encourage the patient to extend the lower limb during stance and allow the BWS to hold them up. It is important to assist the leg only in swing phase, and encourage the patient to extend their lower limb during stance, ie, allow the BWS to prevent the patient collapsing. Count steps for encouragement and take a rest every two minutes at first.

- **Progressing walking on the treadmill.** Increase step length by slowing down the metronome. When step length is nearly normal, increase the speed until step length is compromised. When the knee can be held straight during stance phase, reduce the BWS. Continue to alternate these two strategies until the patient is walking at 0.5 m/s with ≤ 10% BWS. This should result in an easy transition to overground walking.
- **Progressing walking by starting overground walking.** If possible, use a support frame that is moveable thereby allowing overground walking. Lock the wheels of the support frame so that it will only run in one direction. Put markers on the floor to direct step length and constrain step width. Apply only the trunk/pelvis part of the harness, firmly. Push the support frame as the patient walks forwards and then backwards overground. Progress by loosening the vertical support straps, getting the patient to push the frame, and increasing step length and decreasing step width (Figure 4).
- **Monitoring and encouraging walking**. At the beginning, record the number of steps to provide encouragement. Then, as ability improves, record distance covered on treadmill, highest speed and lowest amount of BWS and graph to provide motivation. Record distance and step length during overground walking with BWS. As independent walking overground is possible, use *10-m Walk Test* once a week to monitor progress. As well as timing over the 10 m to calculate speed, count the number of steps and calculate average step length and cadence.

Conclusion

An electromechanical gait trainer is less work for the therapist in that the feet are moved automatically. However, during treadmill training, the patient has to do more work and this may be advantageous in the long term.

Figure 1 Using a splint to support the affected hand on the hand rail.

Figure 2 Using a) custom-made splint, b) pillowcase, and c) theraband to assist with lifting the affected leg forward during swing phase

Figure 3 Using a modified chair to support the therapist's trunk.

Figure 4. Using a portable system to practice overground walking. Harness is for safety only. Markers on the floor encourage a long step length and narrow step width.

USING TREADMILL TRAINING FOR CHRONIC AMBULATORY STROKE PATIENTS

Rationale for using treadmill training

On discharge from rehabilitation, although 60-80% of stroke patients can walk independently (Dean and Mackey 1992, Jorgensen et al 1995) many of them are only able to walk slowly and hesitantly at speeds as low as 0.38-0.80 m/s (Hill et al 1997, Duncan et al 1998, Eng et al 2002, Green et al 2002, Pohl et al 2002). These speeds are insufficient to function effectively in the community, eg, they may be unable to walk fast enough to cross the road or even be unable to leave the house. Treadmill training without body weight support has the potential to drive walking practice.

We propose that treadmill training be viewed as a form of "forced use" which may be used to improve the quality of walking as well as the quantity. The quantity of walking is increased by using the objective measurements of speed and distance that the treadmill provides for feedback in order to increase motivation and adherence to practice targets. The quality is improved because the motion of the treadmill enforces the appropriate timing between the lower limbs and ensures that the hips are extended during stance phase, both of which are critical biomechanical components of walking (Olney et al 1991).

Evidence for using treadmill training

In this population of stroke patients, ie, those who are ambulatory some time after stroke, we are interested in two outcomes. First, does treadmill training without BWS result in better walking capacity (measured using the *6-min Walk Test*), and second, is it detrimental to the quality of walking?

In terms of walking capacity, efficacy of treadmill training without BWS has been examined in a Cochrane review (Moseley et al 2005) which reports that there is no better walking capacity if treadmill training is used than if other physiotherapy interventions are used (MD 16 m, 95%CI -60 to 90). Another systematic review (Van Peppen et al 2004) did not report walking capacity of treadmill training without body weight support. However, both these reviews included acute patients who were still undergoing rehabilitation in hospital. In the only trial included in these reviews which examined chronic stroke, Ada and colleagues (2003) report a distance of 86 m (95% CI 44 to 128) more with treadmill training than sham intervention. Since these reviews, three more trials of chronic stroke have been completed, two comparing treadmill training with sham interventions (Macko et al 2005, Luft et al 2008) and one comparing treadmill training with overground walking (Langhammer et al 2010). Macko and colleagues (2005) report a between-group distance of 43 m (p=0.02), Luft et al report 23 m (p=0.03) while Langhammer et al (2010) report a significant effect (p=0.04).

In terms of walking quality, the Cochrane review reports that treadmill training without BWS may improve walking speed (MD 0.09 m/s, 95% CI -0.02 to 0.20) whereas Van Peppen and colleagues' (2004) report that it did not (SMD 0.58, 95% CI -0.45 to 1.60). Ada and colleagues (2003) report a between-group speed of 0.14 m/s (95% CI 0.03 to 0.25), Macko and colleagues (2005) report 0.02 m/s (p=0.02), Luft et al report 0.04 m/s (p=0.28) while Langhammer et al (2010) report a significant improvement (p=0.03). In summary, it appears that treadmill training without BWS is beneficial in improving walking capacity without detriment to the quality of walking in chronic stroke.

How to apply treadmill training

It is useful to examine how treadmill training was implemented in the four trials which provided evidence that treadmill training was effective in improving 6-minute distance (Ada et al 2003, Macko et al 2005, Luft et al 2008, Langhammer et al 2010). Ada and colleagues (2003) delivered a training program three times a week for four weeks with sessions comprising 30 min of walking. Each session consisted of both treadmill and overground walking, with the proportion of treadmill training decreasing by 10% each week from 80% in Week 1 to 50% in Week 4. Macko and colleagues (2005) and Luft and colleagues (2008) implemented a training program of six months, with 10-40 minute sessions three times a week. The sessions were characterised by progressive increases in duration (five minutes per session every two weeks) and in aerobic intensity (5% heart rate reserve every two weeks achieved by increasing the speed of the treadmill from 0.48 m/s at baseline to 0.75 m/s at six months) and increasing training duration (from 12 minutes to 41 minutes at six months). Langhammer et al (2010) implemented a training program five times a week for two weeks with sessions comprising up to 30 min of walking. The sessions were characterised by progressive increases in treadmill speed to a comfortable level, on average at 0.50 m/s for 12 min.

Improvement in walking capacity (measured by the *6-min Walk Test*) was greater in the Ada and colleagues (2003) study than the Macko et al (2005) and Luft et al (2008) studies. Differences in the programs may account for these results. Both Macko and colleagues and Luft and colleagues only used treadmill training with increasing speed and session duration whereas Ada and colleagues program involved treadmill and overground walking focusing not only on duration but also in quality and automaticity of walking. We therefore suggest that treadmill training programs should include overground walking components where increase in walking speed and increase in step length is encouraged. On the other hand, the improvements in walking capacity were not maintained in the Ada and colleagues' study which suggests that the one month duration was insufficient and that treadmill programs should be of longer duration nearer the six months used by Macko and colleagues (2005).

Tips and advice in using treadmill training

Insights into the practicalities of training ambulatory people after stroke have been gained through carrying out several randomised trials of treadmill training (Ada et al 2003, Ada et al 2009, Kuys et al 2010). Our experience during these trials suggests that attention should be directed to increasing the quality of walking as well as the speed while on the treadmill, reinforcing treadmill training with overground walking, using objective feedback about speed and distance to progress training, and encouraging carryover into community walking. Also, see www.physiotherapyexercises.com for more exercises and text of treadmill training with ambulatory stroke patients.

- **Ensuring the safety of the patient.** Organise medical clearance or a stress test (as per ASCM guidelines) to participate in a treadmill and overground walking program aimed to improve walking capacity and/or aerobic fitness. Always have the safety cord attached and allow the patient to hold the handrail. Make sure shoes are worn.

- **Starting a treadmill training program.** First, focus on increasing step length and then on increasing speed and workload, fitness, and automaticity. Include a warm up involving stretches of the calf and hip flexor muscles against a wall before beginning treadmill training. Given that it has been shown that stroke patients generally achieve higher walking velocities by increasing their cadence relative to step length (Wagenaar et al 1992), it is important to increase step length before adjusting the speed of the treadmill. To increase step length, run the treadmill at a comfortably slow speed and use instructions such as ‘walk as slowly as possible’ or ‘take as few steps as possible’. Make sure the feet point straight ahead during walking. When a normal step length is observed, increase the speed of the treadmill (until step length is compromised). When maximum speed is achieved, increase the incline of the treadmill thereby increasing workload. Also, increase the duration of treadmill training. Finally, automaticity can be promoted by presenting the patient with a concurrent cognitive task (Paul et al 2005, Canning et al 2006), eg, matching the word ‘red’ with the response ‘yes’ " or the word ‘blue’" with the response ‘no’" (Bowen et al 2001). Give feedback about distance walked and time spent walking at the end of each session, and use this information to structure the next session.
- **Walking in different directions on the treadmill.** When the patient is comfortable and can walk well on the treadmill, commence walking in different directions (Figure 5). To begin with, run the treadmill very slowly until the patient becomes accustomed to the different direction. Turn sideways and sidestep along the treadmill. Also, turn around 180 degrees and walk backwards (although this may not be necessary if the treadmill belt can be reversed). In addition, increase the incline of the treadmill and walk sideways and backwards. If the treadmill belt can be reversed, get the patient to turn around, and with more and more incline, get the patient to walk down the slope. Make sure the feet are always pointing straight ahead during these tasks.
- **Including overground walking in the program.** Include overground walking practice aimed at reinforcing improvements in walking pattern and speed achieved on the treadmill. To reinforce any increased step length, use visual cues in the form of non-slip footprints, laid at intervals normal for that patient’s height (Figure 6). As step length approximates normal, encourage patients to walk faster and time them for feedback. Reduce step width and challenge balance by forcing patients to walk along a line forwards, sideways and backwards. Increase workload by introducing stairs and slopes to overground walking practice and promote automaticity by the introduction of dual tasks, eg, walk patients around an outdoor circuit, which included curbs, slopes, stairs and rough terrain while conversing with the therapist without stopping.
- **Progressing walking by focusing on aerobic training.** Use a heart rate monitor (or pulse monitor on treadmill) and begin training at 30-40% heart rate reserve. Spend at least 2 weeks increasing the speed and/or incline of the treadmill to 60-70% of heart rate reserve. If the pattern of walking is poor, use the incline to increase workload. Carry out for 30-40 min, three days/week for at least 8-12 weeks. Then maintain using a home walking program.
- **Progressing walking with a home program.** In addition, institute a maintenance program and regularly update to ensure that gains in walking capacity are maintained over the long term. Devise a program and contract the patient to complete it. The program should involve walking in the community, eg, to the shops, walking around the

block, accessing public transport. It may also include continued attendance at the gym. It may be useful to organize a walking buddy who lives nearby.

- **Monitoring, progression and enhancing compliance**. Organise regular phone calls to discuss the program. Institute formal reviews either in the community or at a facility to measure walking using the *6-min Walk Test* every one to two months and progress the program accordingly.

Conclusion

Treadmill training for ambulatory stroke survivors is sustainable in the long term since treadmills are readily available. They are cheap enough to purchase and therefore exercise can be conveniently carried out at home. On the other hand, if carried out in a clinical facility or in a public gymnasium, practice in groups can involve a social dimension, thereby improving motivation and compliance, and decreasing social isolation. Furthermore, personal trainers can be involved in monitoring and progressing programs.

Figure 5. Walking backwards on treadmill.

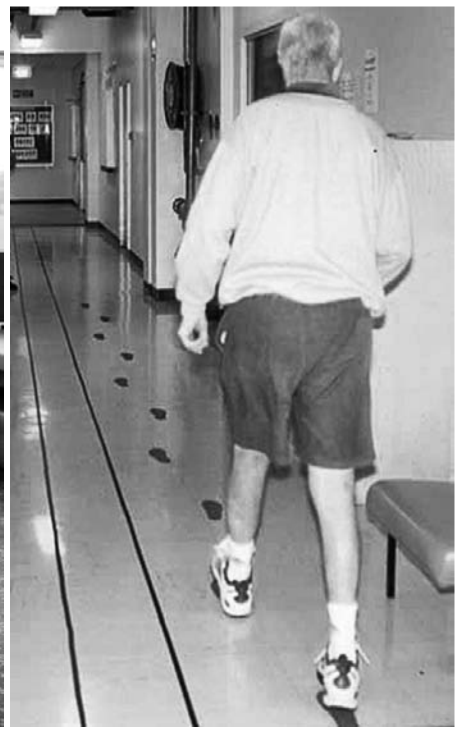

Figure 6. Overground walking reinforcing the gains made on the treadmill using footprints laid at intervals normal for height.

STUDY QUESTIONS AND EXERCISES

1. Explain the two different populations that treadmill training is appropriate for.
2. What are the rationales for using treadmill training in these two populations?
3. How does the application of BWS differ when using treadmill training in these different populations?
4. Is the evidence for treadmill training convincing?
5. Outline a trial that would convince you to implement treadmill training for your patients.
6. How would you explain to your patients why you were using treadmill training with them?
7. Mrs FN is 65 and lives with husband who is still working part time. She is now in hospital 6 days after having has a stroke resulting in right hemiplegia and expressive aphasia. She has severe weakness in most LL muscles and no spasticity. She cannot stand independently, needing help from one person, and she needs substantial help from two people to walk. Design a treadmill training and BWS program for her including how you will progress it over the next 4 weeks.
8. Mr NC is 70 and lives alone with a supportive daughter nearby. He suffered a stroke two years ago and feels his walking is deteriorating. He has moderately strong LL muscles and mild spasticity, a small dorsiflexion contracture and moderately impaired sensation. He also has slight memory loss. He walks independently, but slowly and very carefully at 0.60 m/s and 190 m in six minutes. Design a treadmill training program for him including how you will progress it to include a community walking program over the next 4 months.
9. Find a treadmill training exercise on www.physiotherapyexercises.com and use the resources to prepare a training booklet for one of your patients.

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