WHEELCHAIR SETUP CONSIDERATIONS FOR OPTIMISING ATHLETE HEALTH IN WHEELCHAIR TENNIS

– Written by Samuel Williamson and Alex Cockram, UK

INTRODUCTION

Wheelchair Tennis is a global para-sport and the world leading version of disability tennis. It is played by approximately 8,000 people around the world, spanning 80 countries and provides sporting opportunity for those with a physical disability from grassroots level to the Paralympic Games and all four tennis Grand Slams.

The court, balls, rackets and rules used in Wheelchair Tennis are largely the same as in standing tennis. However, there are two main changes to the rules;

1. The ball is allowed to bounce twice before players play a shot
2. Players play matches seated in a sports wheelchair

Whilst the wheelchair used in competition is subject to rules and certain specifications[1], there are many customisable aspects that can be tailored to suit the needs of individual athletes. Much like other equipment used in tennis (footwear, racket, string) the wheelchair has many parameters that can be changed in order to aid performance. For example larger wheels make it easier to keep momentum whilst moving and make covering the court easier, and changes to seat height can affect reach meaning an athlete can get to more shots. However, the impact of chair set up on preserving athlete health should not be overlooked and is a key factor for players both recreationally and professionally.

This article will discuss various chair set up considerations which, in the experience of the authors, can impact a player's health, as well as discuss case studies in which both large and small alterations to a player's chair has resolved or prevented health complications.

WHAT SHOULD A CHAIR PROVIDE?

Broadly speaking, the physical demands of wheelchair tennis, as with its standing counterpart, can be split in to two groups:

- Movement around the court
- Shot making

A recent systematic review[2] found that athletes cover an average of almost 4km per match with an average rally duration of around 6 seconds. Mason et al[3] also found that players made 12-13 turns per minute depending on the division. Williamson et al[2] also found that athletes made an average 366 shots per match.

Image: © Getty Images for LTA. Printed with permission.

Therefore, the tennis wheelchair must help the athlete achieve both the movement and shot making demands of the game. It should allow athletes to cover the court in the most efficient way possible as well as provide a stable base from which athletes can effectively generate force to strike the ball.

It is the authors experience that setting up the wheelchair to optimise efficiency of movement around the court as well as for shot making, has not only performance benefits, but can have a significant effect on reducing health issues. Given the repeated effort nature of the sport, efficiency is key in reducing unnecessary joint and soft tissue loading, leading to less health complaints.

A BALANCING ACT

In an ideal situation, any change to chair set up would improve both the efficiency of movement and shot making. However, as with many decisions surrounding sporting equipment, changes to any aspect of wheelchair setup are rarely a cure-all and are more commonly a process of weighing up the positives and negatives for the athlete. This is especially true in a sport such as wheelchair tennis, where athletes may present with a wide range of health conditions and impairment types.

Considering the aim of achieving efficiency in movement and stability for effective force transfer for shot making, most choices will be based on two underlying questions:

1. How does the change impact stability and support provided by the chair versus range of movement of the athlete's body segments?
2. How does this change impact the stability of the chair for shot making versus the efficiency of the chair for movement?

Given the goal of improving movement and ball striking efficiency to reduce excess loading of athletes, and with the above-mentioned balancing act in mind, we will now discuss some of the common chair setup parameters, and how a change to these might impact efficiency, loading and health.

THE WHEEL

Wheel size:

Typically, wheel size ranges from 24" for junior athletes to 26" or 27" for senior athletes. Research has shown that larger wheels provide less rolling resistance than smaller wheels during maximal and sub-maximal efforts[4,5]. This leads to reduced physiological demands, less overall effort and therefore lower levels of fatigue when using larger wheels, compared to smaller wheels. Given the repetitive demands of wheelchair tennis, reduced local and global fatigue can play a vital role in reducing injury risk in athletes.

This research also showed that larger wheels were no worse at acceleration from a stationary start than smaller wheels. However, Mason et al[6] found that athletes from both wheelchair tennis and wheelchair basketball (where chair set up is similar to wheelchair tennis), reported that smaller wheels feel easier to accelerate and require less force from a stationary start. Observationally and subjectively according to athletes, smaller wheels are easier to accelerate and require a smaller peak effort when athletes start pushing.

The physical profile of an athlete also plays a part in selection of wheel size. Athletes who may struggle to generate higher peak forces when pushing may benefit from smaller wheels, as there is less effort required to get the chair moving. Typically, this may be athletes who are smaller in stature, have significantly impaired trunk function, or upper limb weakness.

Athletes who are larger in stature, have good trunk function and no upper limb impairment are likely to be able to produce the required forces to accelerate the chair, Therefore, they may benefit from the overall efficiency and reduced loading that larger wheels offer, both physically and physiologically, leading to a reduced risk of upper limb musculoskeletal injury and lower systemic demand.

Camber Angle:

As previously mentioned, a key wheelchair tennis movement characteristic to consider when looking at chair design is the multidirectional nature of the sport, with an emphasis on turning efficiency[3]. Shot making should also be considered, where the setup facilitates rotation and stability during execution of the various strokes, and this is where camber comes into play.

Camber has been defined as the angle of the main wheels in relation to the vertical[7], with an increased camber angle leading to a wider base of support, and therefore greater levels of stability when turning and shot making. It has also been shown that mechanical efficiency at sub-maximal speeds improves with a larger camber angle, without significantly impacting trunk or wrist motion[7]. This is reassuring considering the injury risks associated with greater peak extension values of the wrist within the wheelchair user population[8].

Athletes engaged in court-based sports typically select chairs with a camber angle of 15-24 degrees[9], however 22 degrees is the common choice within wheelchair tennis. Ultimately, this could help to minimise upper limb and trunk load by increasing the stability of the chair and reducing the need to grip or handle the push rim when turning and rotating.

THE SEAT

Size:

Size and fit of the sports wheelchair seat in relation to the athlete is key in preventing health related issues. Efficient transfer of energy between the player and the chair is best achieved when the chair is well fitted, leaving little-to-no room for the athlete to move around in the chair. As the athlete turns, a good connection between the pelvis / upper legs and the chair will allow the athlete to rotate the chair more easily and effectively. Optimising this energy transfer reduces the loading on the upper limbs when propelling the chair, and on the spine and pelvis when turning the chair, reducing the risk of musculoskeletal injury.

Wheelchair athletes, especially those who cannot ambulate at all, are at greater risk of skin health issues than their non-disabled counterparts[10]. A well fitted seat is a key factor in reducing both direct pressure and shearing forces on the skin, which will protect against skin breakdown.

Seat angle:

The inclination of the seat in a tennis chair is often based on the previously mentioned balance between the need for stability and the need for range of movement. Athletes with impaired trunk function will often require more stability from the seat set up, to allow them to be stable in chair propulsion and shot making. This can be achieved by increasing the inclination angle of the seat (raising the front of the seat in relation to the back of the seat) to position the knees higher than the hips. The added stability supports the athlete's spine and again, improves efficiency of energy transfer when the trunk is not able to provide it.

Athletes with good trunk function will be able to create their own stability through the trunk, and therefore do not need as much help from the chair. For these athletes, lowering the inclination angle to raise the hips higher than the knees may be more appropriate. Placing the hips in a relatively more extended position facilitates better use of the hip musculature, pelvic and spinal mobility. The result of this is increased use of the kinetic chain for force generation and dissipation, consequently reducing the risk of musculoskeletal overload along the kinetic chain.

Backrest height:

Like seat angle, backrest height is a component of chair setup which affects stability and range of movement available to the athlete. A higher backrest supplies the athlete with greater stability, but reduces the ability to extend, side-flex, or rotate the trunk during shot making. A lower backrest allows the athlete to have more spinal mobility but requires greater trunk strength to create stability. Backrest height should be determined by considering the individual's function, their need for stability verses movement and the health risks associated with this.

It is important to note that with a lower seat angle and backrest height, the demand

> ***The tennis wheelchair must help the athlete achieve both the movement and shot making demands of the game. It should allow athletes to cover the court in the most efficient way possible as well as provide a stable base from which athletes can effectively generate force to strike the ball.***

on the athlete's trunk and spine increases. Therefore, in athletes with no underlying trunk impairment, there is still a high need for trunk and spinal column strength in all directions, as well as good technical ability. To prevent back injury, caution is advised with aggressively reducing the support from the chair in novice or junior athletes with lower training history whilst they develop the physical capacities required.

THE SEAT-FRAME CONNECTION

Fore-aft position:

The position of the seat in the horizontal plane in relation to the camber bar is known as the fore-aft position. Seat positioning can have a big impact on a players' ability to manoeuvre the chair and the physical exertion associated with court coverage. A seat position which is further back will increase rotational sensitivity of the chair, which can help to reduce the energy cost plus upper limb and trunk load when turning. Consequently, this can have a negative impact on forward propulsion and acceleration, requiring greater levels of trunk flexion/extension to achieve the desired push length. A compromise could be achieved by bringing the seat position forward slightly, however the preference in favour of turning efficiency is seen in athletes set up across the board.

Figure 1: Comparison of non-customised and customised chairs.

Seat Height:

Seat height is linked with the seat angle and therefore hip position. A higher seat can give the athlete an enhanced view of the court and improve overhead reach, whilst helping to lower the relative height of shots to potentially reduce overhead loading of the shoulders. This will reduce the risk of shoulder pain, which is highly prevalent in the wheelchair tennis population.

However, if the seat height is too high then propulsion becomes an issue. The athlete feels unstable when turning, leading to unnecessary stress through the spine. A lower seat position might be more suitable for someone with a shorter stature, relatively shorter upper limb length or limited to no trunk function.

Figure 1 shows a side-by-side comparison of two tennis chairs. The left-hand chair is an adjustable mid-range chair, whilst they right hand chair is a professional chair that has been tailored to suit the needs of the individual using it. Note the difference in seat angle, seat shape and fit, seat fore-aft position, as well as placement of staps and presence of shin guards.

OTHER CONSIDERATIONS

There are many more factors that can impact the efficiency of pushing and shot making which can help reduce tissue overload;

Padding – connection with the seat can be improved in some cases by appropriate padding or other material. The aim is to create a better fit with the seat for efficient energy transfer. However, padding can also play a key role protecting skin, soft tissue and joints that may be vulnerable depending on an athlete's disability (e.g. limb dysmelia, amputation stumps, muscle contractures).

Seat material – there are various seat materials available. Key considerations for this will be based upon the athletes' need for support versus range of movement. Another key consideration here is maintenance of seat material. Wear and tear of material can lead to a change in lumbar spine support, as well as expose the skin to higher risk of pressure areas.

Straps or other restraints – shin guards, hip straps, and trunk straps can all be utilised as a simple, easily applied method to improved player stability and connection with the chair. Similar to padding, these are often easily adaptable or customisable to allow for an athlete's disability and can also be used to support an athlete when returning to play from injury, or a change in condition, without needing a completely new chair.

Chair maintenance – a simple but often overlooked method of reducing rolling resistance and therefore reducing overall effort and load experienced by an athlete is to be proactive with chair maintenance. Tyre pressure should be monitored and corrected frequently, with consideration given to changing tyre pressure for different court surfaces. It the authors' experience,

correcting tyre pressure can significantly reduce athlete reported wrist, shoulder and lumbar spine pain. Casters and bearings should be cleaned and replaced when showing wear. Caster height and size may also need to be changed to optimise the efficiency of the chair across different surfaces. Table 1 outlines two example chair setups for athletes with different physical profiles.

	5'3" C6 Spinal cord injured athlete. • *High level of trunk impairment* • *Reduced upper limb strength.*	*6'2" athlete with single below knee amputation.* • *Full trunk function* • *No upper limb impairment*
Wheel size	*Smaller*	*Larger*
Camber angle	*22 o*	*22 o*
Seat angle	*Bucketed – hips lower than knees*	*Level or slight forward tilt – hips higher than knees*
Backrest height	*Raised to provide adequate support*	*Reduced to allow range of motion*
Seat fore-aft position	*Less rearward to balance turning efficiency and propulsion*	*Further rearward to assist turning efficiency*
Seat height	*Lower*	*Higher*
Straps	*Likely shin, lap and possibly trunk strap*	*Shin and or lap strap. No trunk strap*

Table 1: FExample chair setups for athletes with different physical profiles.

CASE STUDY

Outlined below is a recent example of the journey an Open division wheelchair athlete went through when selecting and modifying a chair to find their desired setup based on their health and physical needs.

The athlete presented with hamstring contractures leading to extreme fixed flexion deformity at both knees as well as fixed inversion and flexion of both ankles and feet. Figure 2 shows her seated position in a mid-range adjustable chair. Whilst this chair does have certain parameters that can be altered, the unique presentation of this athlete meant she was unable to achieve a leg position that allowed a good connection with the seat. This led to compromised pelvic, spinal and shoulder positions for effective propulsion. In addition, due to the position of the athlete's legs in this chair, there were several areas where her skin health was at risk, including contact between the moving wheels and her legs.

Figure 3 shows our modifications to the original setup to help improve her positioning and interaction with the seat, by increasing the seat bucket and removing the cushion to make room for her legs, as well as turning the backrest bar around to create a new platform to sit on. These changes led to a more level pelvic and open hip position, which in turn improved her spinal position and ability to push the chair more effectively.

Whilst this was an improvement on her initial setup, the padding and depth of the new platform seat wasn't sufficient, leading to discomfort and potential pressure sores, and the material supporting her legs was too abrasive, putting her skin health at risk. At this point it became evident that a bespoke fitted chair with a similar design concept was required, so the necessary measurements were taken to ensure a suitable final product was made. In preparation for the arrival of this chair, we designed a strength programme to prepare her trunk and upper limb muscles for the demands of pushing and to help minimise the injury risk. Figure 4 shows her in the new bespoke chair, where she is suitably supported by the seat and in a more optimal position for pushing.

Figure 2: Player in non-customised chair.

Figure 3: Player in chair with temporary modifications.

CONCLUSION

As with any sporting equipment, optimisation and customisation of the tennis wheelchair can have a significant impact on athlete health and performance. The parameters discussed in this article, whilst not exhaustive, should all be considered with regards to the health of the athlete, when selecting or adjusting a chair for wheelchair tennis participation. Key underpinning principles of efficiency of energy transfer, and balancing stability and range of movement should be considered for each decision.

Figure 4: Player in customised chair.

Key points:

- Chair set up is key for managing health risk in wheelchair tennis athletes, including musculoskeletal, skin health, and fatigue factors.
- There is no perfect chair. What is right for one athlete, may not work another.
- Efficiency, stability and range of movement are all important outcomes of changes to chair set up when considering athlete health.
- Do not forget basic chair maintenance – it is simple and can significantly reduce unnecessary tissue loading for athletes.

References

1. *International Tennis Federation (2024) Regulations for Wheelchair Tennis ITF p.98*
2. *Williamson S, Ardern CL, Berry C, Heron N, Janse van Rensburg DC, Jansen MG, McCormick S, Reid M, Sanchez Pay AJ, Saueressig T, Schoonmade L, Shaw RB, and der Slikke R, Webborn N, Pluim B (2024 - Accepted / In-press) The physical demands of wheelchair tennis match play: a systematic review with meta-analysis Sports Medicine*
3. *Mason BS, van der Slikke R, Hutchinson MJ, Goosey-Tolfrey VL (2020) Division, result and score margin alter the physical and technical performance of elite wheelchair tennis players Journal of Sports Sciences 38(8) p. 937-934*
4. *Mason B, van der Woude L, Lenton JP, and Goosey-Tolfrey V (2012) The effect of wheel size on mobility performance in wheelchair athletes Internationa Journal of Sports Medicine 33(10) p. 807-812*
5. *Mason B, van der Woude L, Tolfrey K, Lenton JP, and Goosey-Tolfrey V (2012) Effects of wheel and hand-rim size on submaximal propulsion in wheelchair athletes Medicine and Science in Sports and Excercise 44(1) p. 126-134*
6. *Mason BS, Porcellato L, van der Woude L, Goosey-Tolfrey V (2010) A Qualitative Examination Of Wheelchair Configuration For Optimal Mobility Performance In Wheelchair Sports: A Pilot Study Journal of Rehabilitation Medicine 42 p. 141-149*
7. *Mason B, van der Woude L, De Groot S, and Goosey-Tolfrey V (2011) Effects of Camber on the Ergonomics of Propulsion in Wheelchair Athletes Medicine & Science in Sports & Exercise*
8. *Veeger HEJ, Meershoek LS, van der Woude LHV, Langenhoff JM. Wrist motion in handrim wheelchair propulsion Journal of Rehabilitation Research & Development 1998;35(3):305–13.*
9. *Mason BS, Porcellato L, Van Der Woude L and Goosey-Tolfrey V (2010) A qualitative examination of wheelchair configuration for optimal mobility performance in wheelchair sports: A pilot study Journal of Rehabilitation Medicine 2010; 42: 141–149*
10. *Klenck C, Gebke K (2007) Practical Management: Common Medical Problems in Disabled Athletes Clinical Journal of Sports Medicine 17(1) p.55-60*

Samuel Williamson P.T., M.Sc.
UK Sports Institute, UK

Alex Cockram B.Sc.
Lawn Tennis Association, UK

Contact:
samuel.williamson@uksportsinstitute.co.uk