2012

Wheelchair Basketball

Performance Analysis Rationale & Proposal

This paper provides an in-depth investigation of free throw shooting performance in Wheelchair Basketball. First, a rationale is developed regarding the primary determinants that underpin this activity, the major types of fatigue that may occur and ultimately how this fatigue may influence performance and injury risk to the athlete. Second, a deterministic model and assessment protocols to track changes in free throw performance is proposed. Specifically, a biomechanical analysis of technique and fatigue-induced responses through valid, specific and reliable testing protocols is presented.

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1.0 Introduction

Despite not holding the international reputation and die-hard fan base of traditional, able-bodied basketball, wheelchair basketball remains one of the most popular and fastest growing sports among disabled populations. Boasting over 100 000 players in 80 countries, wheelchair basketball participates in an array of competitions such as the Paralympic Games and the "Gold Cup" World Championships (NWBLAUS, 2012).

Although faced with many obvious and significant disadvantages compared to their able bodied counterparts, the game of wheelchair basketball retains the majority of major rules and scoring system. For example, the standard 10-foot baskets and original court size remain the same across both games, with the only modification being the 'travelling' rule, which is defined by the athlete touching the wheels more than twice after receiving or dribbling the ball. In this case, the athlete must pass, bounce or shoot for goal before resuming wheeling. Further, a classification system to evaluate functional abilities and assist in equality standardisation is employed. Rankings between 1.0–4.5 are given for those exhibiting higher level disability to lower level disability, respectively, with a maximum of 14 points allowed on court at any one time (NWBLAUS, 2012).

Wheelchair basketball requires fundamental skills from the participants, such as shooting, passing and dribbling. Shooting, especially the free throw (FT), can be considered the most important skill as it often determines the final outcome of a game (Malone, Gervais, & Steadward, 2002). The success of FT shooting is discussed in the literature to be dependent on practice, development of a proper technique, positioning of the FT line, and specific movement mechanics involved in the shooting action. Basketball shooting uses a predominant FT pattern. In the 'ready-to-shoot-position' the ball lies in the shooting hand in front of the forehead of the shooter who aims at the basket.

For wheelchair basketball, the ability to shoot accurately and consistently is a major factor for successful performance. In general, individuals with paraplegia have been very successful in wheelchair performance. However, those with tetraplegia have some difficulty playing the sport due to higher spinal cord lesion levels and the resulting arm dysfunction (Numone et al., 2002).

2.0 Primary Determinants of Free Throw Shooting

Based on a significant variance in FT percentage success rates between able-bodied basketball and wheelchair basketball (69% and 45-55%, respectively), Malone and colleagues (2002) suggested that improvements could be achieved through the understanding of the movement mechanics underlying the FT shot. In other words, to achieve an athlete's full potential through training and development, analysing their FT mechanical technique and adjusting it to replicate the best technique possible, it is expected that overall performance can be enhanced.

As a result, this proposal is based on the rationale that if the primary determinants of the most integral skill performed in wheelchair basketball (the FT shot) – and more importantly, the components that make it successful – can be identified, then performance in the game may be enhanced. Further, as fatigue is often a crucial underlying factor in an athlete's ability to remain at their peak form throughout the duration of training and game practices, it is worthwhile assessing it's' influence on the athlete and their injury risk.

With the above in mind, the following deterministic model (Figure 1) demonstrates the proposed components that determine the accuracy of free shots in wheelchair basketball.

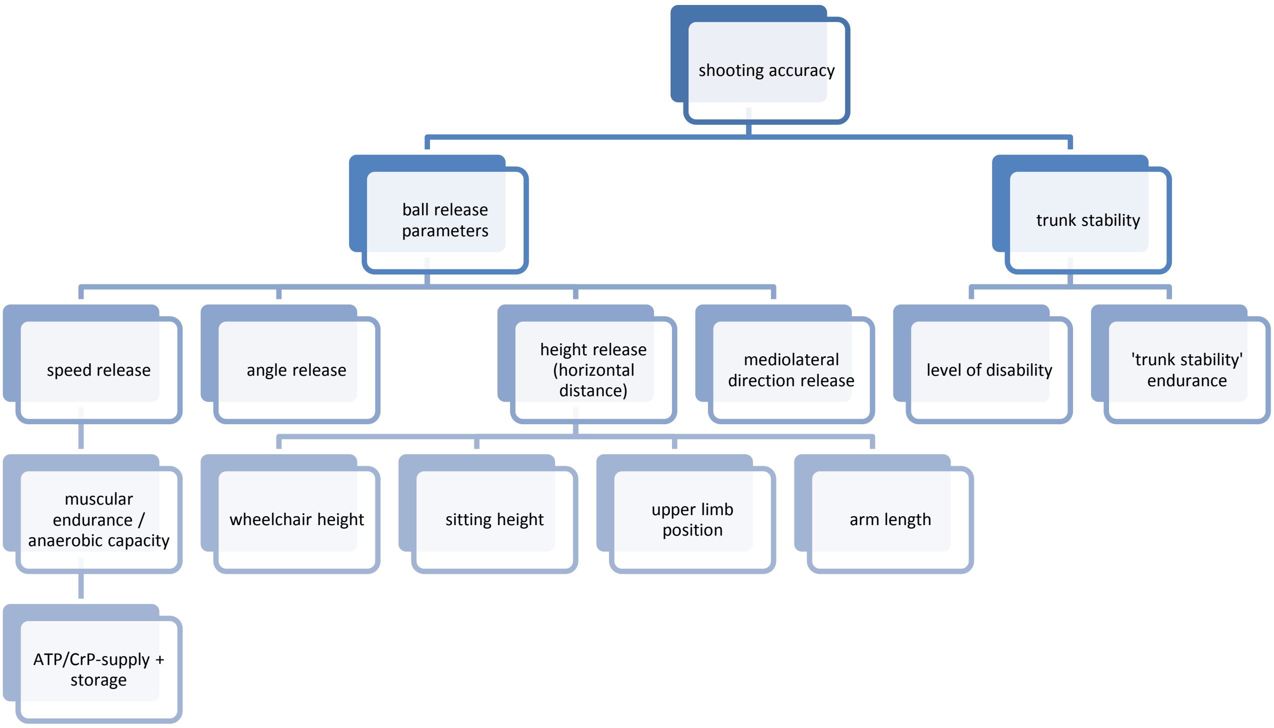

Figure 1. Deterministic model showing the components that affect the accuracy of the free throw (FT) shot.

3.0 Shooting Accuracy

Using the deterministic model to represent the components of FT shooting in basketball, it is evident that many factors determine the outcome or shooting accuracy. At the immediate level, shooting accuracy is affected by parameters surrounding the ball release and the player's trunk stability. Expanding upon the first factor of ball release parameters, these are directly influenced by the ball's speed, angle, height and mediolateral release.

3.1 Ball Release Parameters

The principal factors determining the release and flight characteristics of the ball (and therefore outcome) are the release speed, the angle of ball release and release height (Hay, 1994). These parameters have also been described and used in Malone's (2002) study on the shooting mechanics related to free throw success (Figure 2). The moment in which the ball is no longer in contact with the hand of the player is defined as the time of ball release.

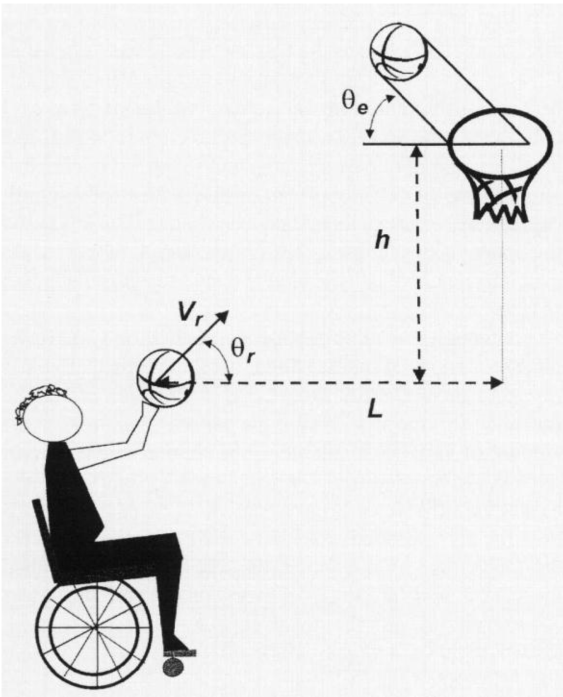

Figure 2: Illustration of release parameters for ball to hoop (Malone et al., 2002).

Part of Miller's (2008b) work was to investigate the coefficients of variation for the primary ball release parameters for accurate and inaccurate FT (as well as accurate short-range and long-range shots). The study showed that inaccurate shots are characterised by a higher variability in the ball release parameters than accurate shots. The ball release speed for accurate shots was less than for inaccurate shots. The ball release angle and ball release height on the other hand, were more variable for accurate shots. These results can be seen in Figure 3.

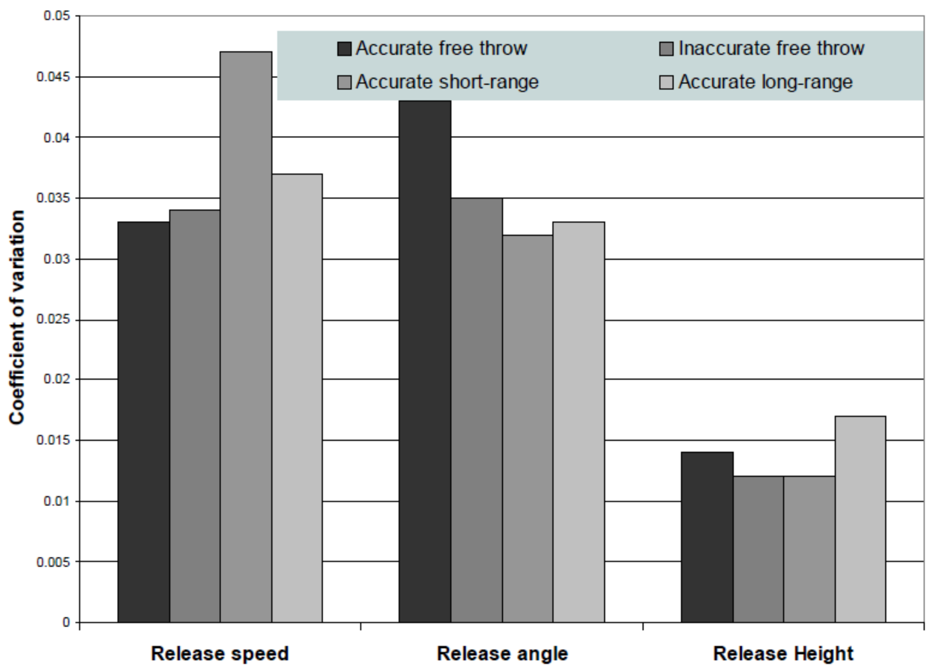

Figure 3: Coefficients of variation for the primary ball release parameters for accurate and inaccurate free throws, and accurate short-range (2.74 m) and long-range (6.40 m) shots (Miller, 2008a).

Moreover, Miller (2008a) stated that inaccurate FT are characterised by greater relative variability in ball release speed, and greater absolute variability in linear speed of segment endpoints at release. By releasing the ball close to the angle requiring the minimum ball release speed, shooters minimise the magnitude of the impulse that must be generated and, by implication, reduce variability in the movement. Miller (2008a) stated that even skilled basketball shooters are unable to generate identical inter-trial ball release parameters.

3.1.1 Release Speed

For any shooting distance, there are infinite combinations of release speed and release angles which will result in a successful outcome. Hay (1994) has shown that, amongst others, the angle of entry of the ball into the basket is an important factor in determining success. This, in itself, is dependent upon both release speed and release angle (Miller, 2008a).

3.1.2 Release Angle

An important characteristic of the skill level of free-throw shooting includes the joint angles of the shooting arm used when releasing the ball. The more expertise a player gains, the less the joint angles vary in each free-throw shot (Schmidt, 2012). In Schmidt's study, the kinematic analysis has been made on the first five shots of each participant, due to the manual tracking of the joint markers at the head of the humerus, lateral epicondyle and wrist joint lateral. The **measurements** gained from this include the angular displacements (u), angular velocities (x) and animated stick figures.

Miller (2008b) noted that an inverse relationship exists between shooting distance and the release angle. According to him shooting distance increases, when the angle requiring minimum release speed decreases. He justified that such an effect is greatest for short range shots due to the (exponential) change in angle of incline from point of release to the basket with respect to distance.

3.1.3 Release Height (Vertical Component)

Release height is measured as the vertical distance from the ground to the centre of the ball. For a given release speed and angle, and thus the greater the relative release height, the longer the flight time and greater the range and maximum height experienced (Miller, 2008b). Miller (2008b) shows that an improved extension of the shoulder and elbow joints increases release height which in turn, improves accuracy.

3.1.4 Mediolateral Direction of Release (Horizontal Component)

The mediolateral displacement refers to changes in trunk movements from side to side. The mediolateral direction of release can be a variable for increased potential stability of the body (Malone, Gervais, & Steadward, 2002). Due to the nature of the FT occurring mainly in the front plane, this determinant will most likely have the least variation in movement.

3.2 Trunk Stability

3.2.1 Level of Disability

The performance of functional activities in sitting is greatly influenced by the level of disability and the quality of support given to the trunk and pelvis. These factors affect the vertical postural alignment and therefore trunk alignment, providing better stability and improved ability to reach (Raine, Meadows, & Lynch-Ellerington, 2009). The research supports the importance of providing postural support to the trunk, to enable the wheelchair player to use their arms for functional activities and also reduce the level of fatigue experienced (Raine et al.).

In Wheelchair basketball, the less disabled (higher scored) players typically have a higher seat position than other players, which allows easier rebounding and shooting at goal. However this may in turn decrease stability and alter the manner in which muscular forces are applied to the hand rim (Raine et al., 2009).

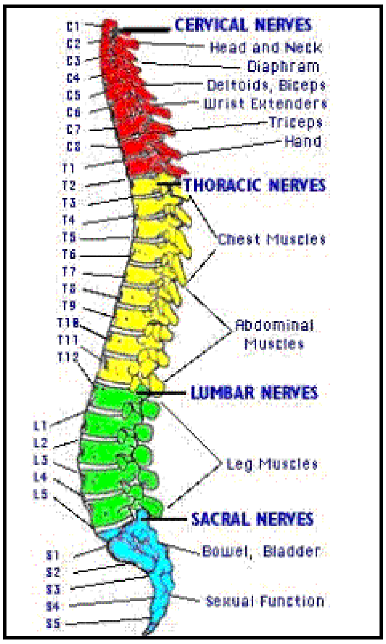

Figure 4: Spinal Innervation (Begin to Dig, 2012).

A paralysis is defined by a disturbance/dysfunction of motor, sensory and autonomic nervous system. Depending on the level of paralysis, certain areas may be affected (see Figure 4). Most typically, the respiratory function, circulation and thermoregulation are impaired (Tanaka & Watanabe, 2012).

The respiratory function may be in deregulation as damage to the cervical and thoracic spine causes a partial or complete paralysis of the muscles between the ribs and the respiratory muscles, as well as an abnormal neural control of the diaphragm. The circulation can be affected by mental stress which causes severe headache and confusion. Furthermore, dysfunction of the thermoregulation can cause a rise in body temperature of up to 39 degrees Celsius. This is due to impairment of peripheral heat regulation, anhidrosis in paralysed body areas (failure of sweat), simultaneously intense sweating in unaffected body parts, collectively known as peripheral accumulation of heat (Raine et al., 2009; Tanaka & Watanabe, 2012).

3.2.2 Trunk Stability Endurance

The goal of good seat positioning is to provide adequate postural support to enable appropriate alignment and stability of the trunk and limbs, therefore reducing the fear of falling and need for compensatory fixations appropriate to that postural set. This will give the patient the foundation base of support (BOS) on which to move actively and appropriately within their chair and wider environment. Seating and positioning may require the use of external scaffolding to support hypotonic areas using towels and pillows. This is especially important in the patient with low arousal/minimally conscious state (Raine et al., 2009).

Moreover, armchair or wheelchair seating must provide adequate support to maximise comfort and enhance postural and functional activity. Without appropriate and stable positioning during seating, the patient is at risk of developing postural dysfunctions, which can interfere with the accomplishment of functional skills and ongoing recovery. Discomfort and back pain is common in wheelchair users. A thorough assessment must be completed to determine the optimal seating and mobility system for each patient (Raine et al., 2009).

Throwing movement patterns are statically executed and therefore disabled players have to relate all sports actions with the rest of their body functions and with the help of a wheelchair. The wheelchair itself guarantees a stabile throwing position; hence the player has to optimise his set position for his throwing patterns.

4.0 Influence of Fatigue on Performance & Injury Risk

Several studies have reported the high incidence relationship between shoulder kinetics and shoulder pathologies; athletes who propel with higher shoulder forces and moments are more likely to have shoulder injuries (Finley & Rogers, 2004). The aetiology of shoulder pathology is described in various forms. Possible causes include the repetitive nature of wheelchair propulsion, the high-strength requirements placed by wheelchair propulsion on the shoulder muscles, loading of the joints at extremes of motion and muscular weakness or imbalance (Finley & Rogers; Raine et al., 2009; Rocco & Saito, 2006).

Lal and colleagues (as cited in Mercer et al., 2006) found that an increased level of wheelchair activity (independent mobility compared with assisted mobility) was correlated to degenerative changes in the shoulder. Further, the repetitive task of wheelchair propulsion, the weight-bearing required for transfers and the activities of daily living, all increase the stress on the upper limbs. The most common pathologies documented are rotator cuff impingement, glenohumeral instability, and biceps tendonitis (Finley & Rogers, 2004; Raine et al., 2009, Rocco & Saito, 2006).

In wheelchair basketball, fatigue in trunk stability endurance leads often to an increase of pathological movement patterns and therefore to commonly found injuries and diseases of the neck, back and shoulder regions. In general, the greatest risk of injury to the shoulder exists during the basketball game itself (sports clinic deal with up to 16% of injuries due to basketball), with the risk of suffering an injury to the shoulder during the game (compared to training) is almost four times greater. The typical mechanism of injury is collision with an opposing player (Mercer et al., 2006).

5.0 Assessments of Performance & Fatigue

Both performance and fatigue are best observed under either game play situations (e.g. game/event) or through multiple repetitions of an activity (e.g. FT shooting). With this in mind, we chose to assess these determinants through biomechanical video analysis and reliable, valid and wheelchair basketball specific field tests. Inclusion and omission criteria are discussed below.

5.1 Biomechanical Video Analysis

The 'SiliconCoach Live' application is a web based video analysis solution which can be utilised easily in clinical training settings. Videos can be uploaded in any format, be analysed, annotated on, shared and discussed with players and coaches. It allows interpreting detailed distances as well as angle measurements, overlaying the video showing a physical activity, and presenting the athletes their own technique. This eliminates verbal misunderstanding and accelerates their learning from basic movements through to more complex skills. The video can also be played in slow motion or frame by frame to see movements in detail, as well as capturing snapshots of key points. Useability is enhanced by videos being uploaded from any recording device.

McDonald et al. (2011) investigated the accuracy and reliability of a SiliconCoach Video Analysis protocol to assess core stability. According to this research, the used software is an appropriate, accurate and reliable solution for assessment and offers qualitative video analysis packages. For this proposal, SiliconCoach Live was used as the tool for video analysis. This was chosen over Dartfish as the system enabled processing of any video format without the need to convert manually. Moreover, the features in SiliconCoach were sufficient for the analysis to be done. The values chosen are forward-backward/medio-lateral lean of the trunk, shoulder flexion/extension/abduction/adduction/internal rotation/external rotation, elbow flexion/extension/pronation/supination and wrist flexion/extension during shooting.

5.2 Other Tests

Many assessment techniques exist to measure changes in performance and the subsequent outcomes due to fatigue. Some of these include aerobic/anaerobic capacities, psychological testing and coach and player ratings.

5.2.1 Aerobic + Anaerobic Capacities

Wheelchair basketball features a combination of both intermittent medium and intense phases of play, metabolically and biomechanically similar to its able-bodied counterpart. Specifically, a study by Coutts (1992) demonstrated that 64% of the players' game time is spent in propulsive action, with the remaining 36% in braking. Due to this alternating aerobic-anaerobic nature of the game, it is suitable to evaluate both aerobic and anaerobic capacities of participating athletes (Brunelli et al., 2006).

Objective data such as heart rate (peak, recovery, % increase/decrease, etc.) and time to complete each sprint (total time, time improvement, etc.) can provide valuable and unbiased information regarding an athlete's fatigue rate. Relative to the sport of wheelchair basketball, Brunelli and colleagues (2006) adapted the traditional basketball 5x20m repeated sprint ability (RSA) test. This involved intermittent intervals (all-out sprints with recovery periods) acceleration to peak velocity and some skill ability through wheelchair manoeuvring. However, most importantly this allowed for data collection of interacting aerobic and anaerobic energy systems.

5.2.2 Psychological Testing

Psychological testing like questionnaires, diaries and player interviews can be employed for both performance and fatigue measures. Specifically, being able to determine under what circumstances each individual's performance is increased (and alternatively, decreased) can provide valuable information to training methods. Understanding what makes them 'tick', what level of arousal they operate best at, and what techniques such as self-talk, goal-setting, feedback they employ (if any), coaches and support staff are better able to get the most from their athletes performance. Specifically, research has shown that better performance is marked by certain levels of mental skills and attributes. These and their subsequent tests are presented in Table 1.

Mental Skills & Attributes	Current Associated Tests
Mood states	Profile of Mood States (POMS)
Performance strategies	Test of Performance Strategies (TOPS)
Task & ego orientation	Task & Ego Orientation in Sport Questionnaire (TEOSQ)
Coping skills	Athelte Coping Skills Inventory (ACSI-28)
Sport motivation	Sport Motivation Scale (SMS-28) Intrinsic Motivation Inventory (IMI)
Trait anxiety	Sport Competition Anxiety Test (SCAT) The Sport Anxiety Scale (SAS)

Table 1. Psychological tests currently used to assess sports performance.

When the central system is fatigued, numerous psychological factors are also affected. For example, concentration and attentional processes are significantly reduced, leading to decreased performance. Further, ability to adjust to feedback regarding such performance (e.g. shooting success rate) is decreased. In addition to performance decrements due to central fatigue, this decline in the ability to remain focussed on salient stimuli – and at the most effective level (under vs. over arousal) – subsequently increases an athlete's injury risk.

5.2.3 Coach & Player Ratings

Coach and player ratings are often implemented as they provide a subjective assessment for each player. Specifically, De Groot, Balvers, Kouwenhoven, & Janseen (2012) specified 7 skill domains in wheelchair basketball; speed, start speed, agility, shooting, passing, ball handling and endurance. These can be assessed by both coach and player across different time periods (inter-rater design) or comparatively (intra-rater design) and have been shown to be reliable and valid measures (Zwakhoven et al., 2003).

5.3 Field Tests

Field tests attempt to track athlete improvements and decrements over time (e.g. throughout seasons or training periods), are cost effective and allow for measurement of game-specific skills. However, they are less reproducible, are more difficult to standardise than laboratory tests and must be interpreted with caution as they can be influences by confounding variables such as environmental conditions (Brunelli et al., 2006; De Groot et al., 2012).

Based on results in the literature supporting their reliability and validity, in addition to video analysis, field testing was accepted as the most suitable and accurate measure of performance and thus represent the featured component of our current proposal. To track changes in performance and fatigue, the following skill-specific field tests and their protocols for our study are described below.

1. 20m sprint with ball (speed + ball handling)

This protocol begins with the athlete holding the ball in a stationary position, and pushing 20m as fast as possible whilst adhering to IWBF dribbling rules (Figure 5). Time is recorded by a stopwatch, beginning once the front wheels cross the start and concluding once the front wheels cross the finish line. The best of 2 attempts is recorded, with the quicker (shorter time) representing a better performance (De Groot et al., 2012).

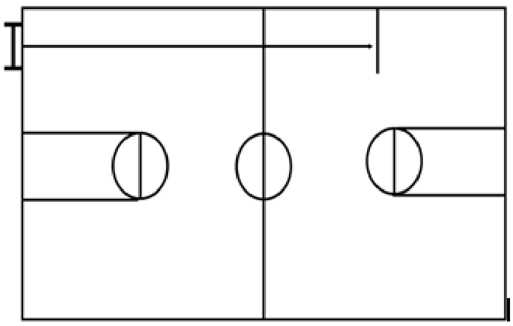

Figure 5. Standardised set up of the 20m sprint with ball field test used to assess speed and ball handling.

2. Ball Pick-up (ball/wheelchair handling + speed)

Propelling from a stationary position, the athlete picks up a total of 4 balls from the floor (twice with left hand and twice with right hand). After collecting each ball, it is placed on the lap and the athlete pushes once before releasing the ball and moving onto the next (Figure 6). Scoring is determined by the total time taken to complete the test, with quicker (shorter time) representing better performance (De Groot et al., 2012).

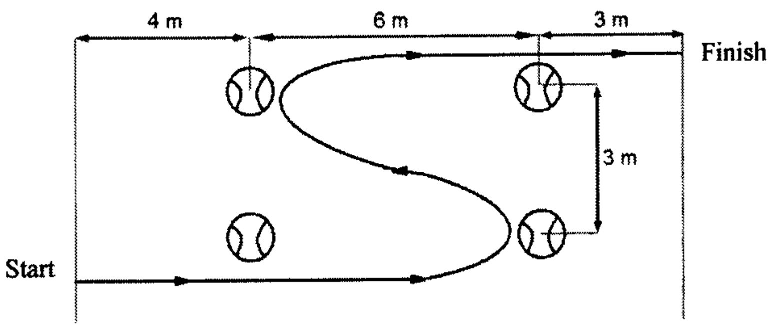

Figure 6. Standardised set up of the ball pick-up drill used to assess ball/wheelchair handling and speed.

3. Suicides (speed, endurance + wheelchair handling)

Suicides allow for measurement of maximal speed through 4 sprints. Each sprint begins at a different line on the court. 4 laps are undertaken per test; to foul line and return, to half foul line and return, to far foul line and return and to far baseline and return (Figure 7). Total time to complete the test is recorded with quicker (shorter time) representing better performance (De Groot et al., 2012).

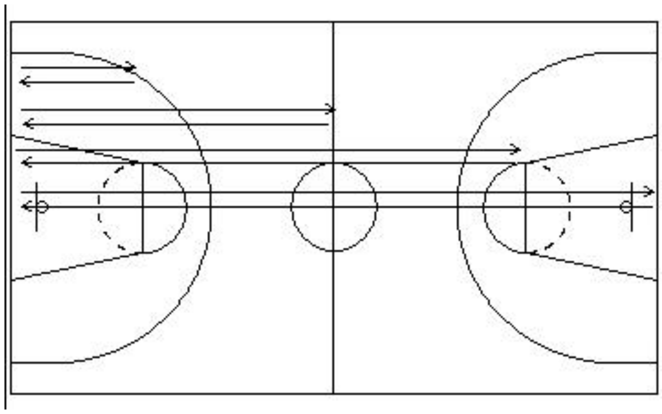

Figure 7. Standardised set up of the suicide testing protocol used to assess speed, endurance and wheelchair handling.

4. Lay-up (ball handling + shooting accuracy)

Starting behind the 3-point line (and returning after each attempted shot), the athlete has 1-minute to perform as many successful lay-ups as possible, whilst adhering to IWBF dribbling rules (Figure 8). Scoring is assessed by the following scheme; 3 = ball passes through hoop, 1 = ball touches ring, but fails to pass through and 0 = ball does not touch ring at all. Higher scores reflect better performance (De Groot et al., 2012).

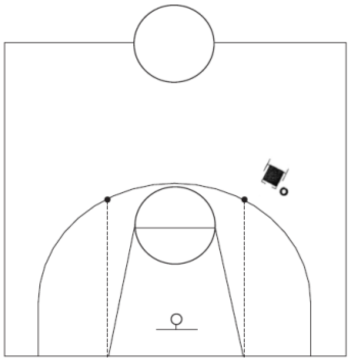

Figure 8. Standardised set up of the lay-up drill used to assess ball handling and shooting accuracy.

5. Spot-shot (ball handling + shooting accuracy)

In this protocol, 5 set shots are attempted from 4 positions around the key; 2 at top of key (left and right) and 2 at base of key (left and right) (Figure 9). Scoring is calculated with 3 = ball passes through hoop, 1 = ball touches ring, but fails to pass through and 0 = ball does not touch ring at all. With a total of 20 shots, scores range from 0-60, with higher representing better performance (De Groot et al., 2012).

Figure 9. Image of an athlete performing a spot-shot or free throw (FT). This drill is used to assess ball handling and shooting accuracy from different areas around the key.

6. Pass-for-accuracy (pass accuracy)

Beginning with the wheelchair's front wheels behind a line placed 7m from a target, the athlete is required to aim for the centre of a fixed target 10 times. Any form of pass is acceptable. Figure 10 indicates the different scoring regions (3, 1 and 0), with a higher score reflecting better performance (De Groot et al., 2012) .

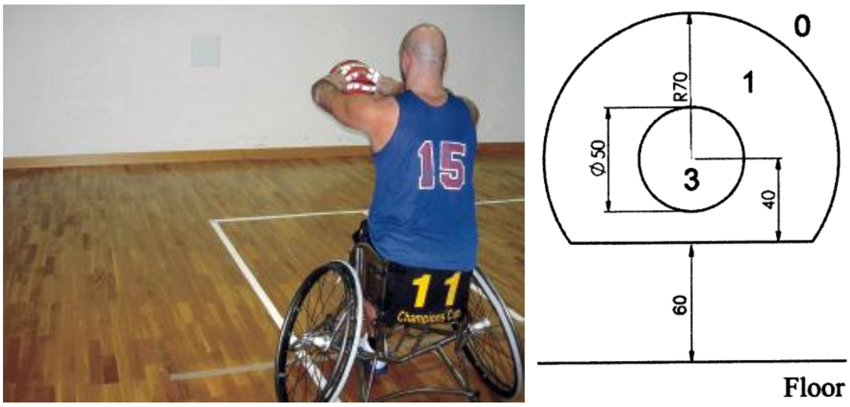

Figure 10. Demonstration (left) and marking criteria (right) of the pass-for-accuracy field test.

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