WHEELCHAIR BASKETBALL AND AGILITY

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ABSTRACT

Wheelchair basketball players need to have strong fundamental wheelchair skills for optimal performance. Success in wheelchair basketball is largely dependent on a player's ability to outmaneuver his/her opponent through the use of agility skills. Given that there are currently no criterion planned agility or video reactive agility tests for wheelchair basketball, further research in this area is warranted.

The purpose of this series of studies was to evaluate the validity of agility tests specific to wheelchair basketball and to investigate the primary anthropometric and physiologic determinants of agility in wheelchair basketball players. Study 1 found that both the Williams Wheelchair Agility test and the Illinois Agility test demonstrated construct validity (Williams: 18.97 ± 0.53 s vs. 20.13 ± 2.22 s for elite and competitive groups, respectively, p=.048; Illinois: 26.34 ± 0.66 s vs. 27.95 ± 2.57 s for elite and competitive groups, respectively, p=.026). Study 2 found that the video reactive agility test also demonstrated construct validity and appears to be effective in detecting reactive agility in wheelchair basketball players (Elite: 7.72 ± 0.36 s vs. Competitive: 8.03 ± .38 s, p=.04). Study 3 found that 20-m straight-line sprint speed test and medicine ball toss were the strongest predictors of planned agility (Williams: R^2=.75; Illinois: R^2=.94). 20-m straight-line sprint speed was the strongest predictor of reactive agility (R^2=.41). The strongest predictors for the 5-m straight-line speed test were the medicine ball toss and relative strength (R^2=.80). The medicine ball toss was also the strongest predictor of 20-m sprint times (R^2=.68). Due to the potentially significant impact agility has on performance, larger studies focusing on wheelchair basketball planned and reactive agility are warranted.

DEDICATION

This dissertation is dedicated to my boyfriend, family, and friends who were a continuous voice of encouragement and support from start to finish. I could not have completed this manuscript without you!

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
FIBA	International Basketball Federation
ICC	intraclass correlation coefficient
IWBF	International Wheelchair Basketball Federation
NWBA	National Wheelchair Basketball Association
RPE	rating of perceived exertion
ROM	range of motion
SCI	spinal cord injury
SEE	standard error of the estimate
SEM	standard error of measurement
SPSS	Statistical Package for the Social Sciences

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CHAPTER 1

INTRODUCTION

Wheelchair basketball is a fast-paced contact sport comprised of quick explosive movements (Curtis & Black, 1999; McInnes, Carlson, Jones, & McKenna, 1995; Owen, 1982; Vanlandewijck, Theisen, & Daly, 2001; Wang, Chen, Limroongreungrat, & Change, 2005). The official rules of wheelchair basketball are similar to the running game except for some necessary amendments in order to make basketball feasible and safe to play while propelling a wheelchair. Wheelchair basketball is played on the same size court (including height of basket, key, foul line, 3-point line, and uses the same ball size and shot clock) as running basketball and is officiated by licensed referees. A game consists of two 20-minute halves or four 10-minute quarters depending on which rules are being followed (National Wheelchair Basketball Association [NWBA] or International Wheelchair Basketball Federation [IWBF]).

Many of the drills and training practices currently being used in wheelchair basketball have been adopted from running basketball, likely because of the similarities between the two sports. Nevertheless, there are also several differences, which probably explain why some of the drills and training practices adopted by wheelchair basketball coaches and players have been viewed as having varying levels of effectiveness (Frogley, 2010). Two notable differences between running and wheelchair basketball are that each requires a specific skill set unique to the demands of the mode of locomotion, and each is comprised of athletes with different physical functional abilities.

For example, in wheelchair basketball, when ball handling, one hand is used more often than two because one hand is needed to push or maneuver the wheelchair while the other hand dribbles, catches, or passes the ball (Frogley, 2010). Another major difference is an athlete's lateral mobility is diminished when propelling a wheelchair compared to running. As a result of this decreased lateral mobility, a major tactical strategy is to block your opponent from moving where s/he wants to go. Thus, wheelchair basketball players need to have strong fundamental wheelchair skill-related fitness, such as agility, for optimal performance. Frogley (2010) recommends that wheelchair basketball players focus on maximizing their agility, because if a player cannot effectively move her/his wheelchair up and down the basketball court and change direction rapidly, it does not matter how well s/he performs the other skills of the game.

During a wheelchair basketball game, players constantly react to their opponents, their teammates, and the ball. Therefore, the more agile players are likely to get closer to the basket, which should lead to scoring more points. Defensively, more agile players are better equipped to stop their opponents farther from their basket, thus decreasing the number of high percentage shots inside the key, resulting in a lower score for the opposing team.

Given the importance of agility to wheelchair basketball success, valid measures of agility are important in order to accurately characterize athletes and document when improvement is needed. However, to date there are only a few studies that have attempted to validate field tests with an agility component for wheelchair basketball (Brasile, 1986, 1990; de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999).

A recent study by de Groot et al. (2012) used a slalom test as a measure of agility. The authors reported a high correlation between the slalom test and speed ($r > 0.80$) but found no significant difference between IWBF high classification (players with the most physical function; e.g. least lower body impairment; rated 4-4.5) and low classification players (players with the least physical function; e.g. spinal cord injury (SCI); rated 1-3.5). This approach attempted to validate agility based on physical function (players' classification). When the de Groot et al. (2012) participants were grouped based on league competition levels (e.g. elite vs. competitive), mean agility scores differed, and the premier league players (elite) recorded the fastest times. The assumption is that the higher skilled players (at all classifications) are playing in the premier league (highest competitive league). The results of the de Groot et al. (2012) study indicate that agility may be more dependent on competition level than functional classification level.

In other studies, a 1-minute Figure-8 Test was used to measure a player's wheelchair maneuverability as part of a performance index that could be used to represent agility (Brasile, 1986, 1990). The main focus of these studies was to assess the relationship between players' classification levels and skill proficiencies. In terms of agility, Brasile's findings were similar to the results of the de Groot (2012) study cited above, i.e. the Figure-8 Test did not distinguish higher classification and lower classification players in terms of agility (Brasile, 1986, 1990). However, it is important to note that these studies used different classification systems to define their classification groups. De Groot's (2012) low classification group included classification levels 1-3.5 based on the IWBF classification system, whereas Brasile's low classification groups included classification levels 1-2 based on the NWBA classification system. This means that de Groot's low classification group included higher physical functioning athletes (3 and 3.5). Even though there was a larger physical functional difference between Brasile's (1986, 1990) high and low classification groups compared to de Groot's, no differences were detected in any of the studies in terms of agility times. One interpretation is that the assessments used to evaluate agility lacked construct validity because they did not distinguish between those who likely had low agility (low classification) from those who likely had high agility (high classification). Another explanation is that those with high classifications had less wheelchair basketball experience. Conversely, classification level may not differentiate agility level. One possible way to avoid this ambiguity is to group players according to competition level (elite vs. competitive) instead of classification (high vs. low).

All of the wheelchair basketball studies that have included an agility component have used planned agility tests in which the exact movement pattern is known and thus there are no anticipatory or decision-skills required (Brasile, 1986, 1990; de Groot et al., 2012; Vanlandewijck et al., 1999). Some researchers claim that this method of agility testing does not reflect the on-court cognitive agility demands of team sports, and planned agility tests are limited in terms of ecological validity (Henry, Dawson, Lay, & Young, 2011).

It has recently been acknowledged that in most team sports, directional changes are often initiated in response to external stimuli, such as the movement of an opponent or ball (Henry et al., 2011). This suggests that agility consists of perceptual and decision-making skills (cognitive component), as well as physical components (change of direction). Reactive agility refers to an unknown change of direction that is determined by a reaction to an external stimulus (Young, James, & Montgomery, 2002). Video reactive agility tests have been developed in an attempt to measure the cognitive component of agility (reactive agility). For example, a sport-specific cue (e.g. a pass projected onto a screen) requires a player to process visual information and react appropriately. Video reactive agility tests differ from reactive agility tests in that video reactive agility tests feature a video projection of a player doing a sport-specific skill, while reactive agility tests feature a generic stimulus (e.g. light, sound). Whereas there are some video reactive agility tests currently in use, there are no reports in the scientific literature regarding their validity with wheelchair basketball athletes.

Given that there are currently no criterion tests of planned agility or video reactive agility for wheelchair basketball, further research in this area is warranted. Success in wheelchair basketball is largely dependent on a player's ability to outmaneuver his/her opponent through the use of agility skills. Therefore, it is important for players to have valid measures of agility and reactive agility so that these skills can be optimized. Also, it is important for coaches and trainers to have a valid instrument to measure wheelchair basketball players' agility skills in order to tailor the design of training programs.

In addition to a validated test of planned agility and reactive agility for wheelchair basketball, there is also a need to profile players in order to determine which variables are most related to agility. The factors believed to influence a player's wheelchair agility are: anthropometric, upper-body strength and power, speed, and wheelchair configuration (Rice et al., 2011; Vanlandewijck et al., 2001). However, the exact relationship between these factors and wheelchair agility performance is unclear. Determining this information would assist coaches in selecting the players expected to be the most agile as well as identify variables related to agility that can be targeted with training programs.

Purpose

The purpose of this series of studies was to evaluate the validity of agility tests specific to wheelchair basketball and to investigate the primary anthropometric, physiologic, and wheelchair configuration determinants of agility in wheelchair basketball players.

Study 1. The purpose of study 1 was to determine the construct validity of the Illinois Agility test and the Williams Wheelchair Agility test for wheelchair basketball players.

Study 2. The purpose of study 2 was to determine the construct validity of a video reactive agility test for wheelchair basketball players.

Study 3. The purpose of study 3 was to determine if a wheelchair basketball player's athletic profile (i.e. descriptive, anthropometric, upper-body strength and power) and wheelchair configuration are related to planned agility, reactive agility, and/or speed.

Hypotheses

Study 1. The hypothesis for Study 1 was:

1) Planned agility test times would be faster for elite compared to competitive wheelchair basketball players.

Study 2. The hypothesis for Study 2 was:

1) Video reactive agility test times would be faster for elite compared to competitive wheelchair basketball players.

Study 3. The hypotheses for Study 3 were:

1) Planned agility and reactive agility are related to the following descriptive variables:
    a. Age
    b. Previous sport experience prior to playing wheelchair basketball
    c. Number of years playing wheelchair basketball
2) Planned agility and reactive agility are related to the following anthropometric variables: height, bodyweight, body composition, trunk and arm length, wrist and shoulder range of motion.
3) Planned agility, reactive agility, and speed are directly proportional to upper-body strength and power.

4) Planned agility, reactive agility, and speed are related to wheelchair configuration [seat height, camber (the angle of the wheel in relation to the wheelchair frame), wheelbase length, wheelchair mass, and tire size].

Significance of the Study

For athletes, coaches, and trainers it is essential to have valid field tests to measure skill-related fitness. Currently, there are no gold standard tests for wheelchair basketball skills (de Groot et al., 2012). Evaluating construct validity of the Illinois Agility test, the Williams Wheelchair Agility test, and a video reactive agility test for wheelchair basketball players will provide coaches, athletes, and others working with wheelchair basketball players with valuable tools that can be confidently used to assess agility in their wheelchair basketball athletes. Better understanding of those factors related to agility will help in tailoring training methods to specific needs, which in turn may enhance sport performance. Furthermore, establishment of valid agility tests may encourage the wheelchair basketball community to adopt standardized testing protocols. As a result this could lead to the formation of performance norms. The development of performance norms would allow for national and international skill comparisons.

Definition of Terms

Agility

Currently there is no agreement in the able-bodied sporting community on a precise definition of agility (Sheppard & Young, 2006). This could be partially due to the fact that agility is a complex skill that involves a variety of different sport-specific movements. Various definitions of agility include the ability to rapidly change direction, explosively start and stop, decelerate and accelerate, and maintain dynamic balance (Baechle & Earle, 2009; Chelladurai, 1976; Little & Williams, 2005; Young & Farrow, 2006). No attempts have been made to clearly define agility in wheelchair sports. In the wheelchair basketball literature, agility and wheelchair maneuverability are often used interchangeably. Wang et al. (2005) stated that wheelchair maneuverability consists of propulsion, starting, stopping, and changes of direction. For the purpose of this series of studies, wheelchair agility refers to the ability to rapidly move and change the direction of one's wheelchair.

Reactive Agility

Agility is also believed to be influenced by a reaction to a stimulus. Therefore, Sheppard et al. (2006) suggested a new definition of agility: "…a rapid whole-body movement with change of velocity or direction in response to a stimulus." This implies that agility consists of perceptual and decision-making skills (cognitive component), as well as physical components (change of direction). Accordingly, in this series of studies, reactive agility refers to a change of direction in response to a stimulus (Young et al., 2002).

IWBF player classification

Wheelchair basketball players are a heterogeneous group of individuals who have a wide range of physical functioning. Some players are able to walk and only use a wheelchair for playing basketball; other players have a spinal cord injury (SCI) and use a wheelchair for daily mobility. Players are assigned a point value ranging from 1.0 (players with the least physical function; e.g. SCI) up to 4.5 (players with the most physical function; e.g. least lower body impairment) (International Wheelchair Basketball Federation, 2010). The IWBF classification system is based on a player's ability to execute fundamental basketball movements: wheelchair propulsion (stops/starts, sprinting, turning), dribbling, shooting, passing, catching, rebounding, and reacting to contact (International Wheelchair Basketball Federation, 2010). During a game, the total classification points must not exceed 14 for the 5 players on the court for a given team.

Thus, teams are not comprised entirely of players with minimal disabilities (class 4-4.5) because the 14-point maximum requires teams to play athletes of all classes (disabilities) (Tweedy & Diaper, 2010). The aim of the classification system is to minimize the impact physical impairments have on the outcome of a competition (International Wheelchair Basketball Federation, 2010). This is similar to other sports' utilization of age, gender, and weight classes to minimize the impact of physical advantages (Tweedy & Diaper, 2010).

Wheelchair basketball studies often use player classifications to group participants. This allows comparisons of performance measures based on physical functioning, such as comparing 3-point shot mechanics of high class (3-4.5) versus low class players (1-2.5). Another common grouping of participants is by competition levels, which allows comparisons of performance measures regardless of classification. An example of such grouping would be to compare national team players to local recreational team players. Both teams will be comprised of players ranging from 1.0-4.5. The assumption is that the national team players will be more skilled than the recreational team players for a given classification division. This means that a 1.0 national team player ought to be more skilled than a recreational 1.0 classification player. For the purposes of this series of studies, players will be grouped by competition level (an index of wheelchair skills).

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CHAPTER 2

VALIDITY OF AGILITY TESTS IN WHEELCHAIR BASKETBALL

Introduction

A major tactical strategy in wheelchair basketball is to block opponents from their desired destination. Consequently, wheelchair basketball players need to have strong fundamental wheelchair skills for optimal performance. These skills include a player's ability to outmaneuver his/her opponent, which requires agility (Rice et al., 2011; Vanlandewijck, Theisen, & Daly, 2001). However, there is no consistent definition of wheelchair agility in the scientific literature. Thus, for the purposes of this study, wheelchair agility refers to the ability to rapidly move and change the direction of one's wheelchair.

To date, only a few studies have attempted to evaluate the validity of agility tests for wheelchair basketball players (Brasile, 1986, 1990; de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999). These studies investigated the slalom test or variations of a Figure-8 Test with and without a basketball as a part of larger skill proficiency tests. Higher skilled players performed both the slalom and the Figure-8 Tests in faster times than individuals at lower competition levels, thereby suggesting some degree of construct validity for these tests (Brasile, 1986, 1990; de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999). However, agility in wheelchair basketball is comprised of many different actions such as starting (acceleration), stopping (deceleration), pivoting, turning, forward and backward propulsion, and changes of direction (Wang, Chen, Limroongreungrat, & Change, 2005). The slalom test and the Figure-8 Test encompass mainly turning while propelling forward around a marked course. This requires a player to accelerate and decelerate (to maintain balance) as she/he weaves around the course as quickly as possible. For maximal ecological validity, a wheelchair basketball agility test should include more of the skills (listed above) that a wheelchair basketball player uses during a game.

Currently, there is no criterion test of agility for wheelchair basketball players, despite the recognized importance of having agile players for a successful team. The absence of criterion tests for wheelchair basketball agility makes it difficult to establish performance norms or to measure change in a player's agility skills. Agility tests that are valid for running basketball, such as the Illinois Agility test or the T-test, could possibly be used for wheelchair basketball, but they need validation for use in this context. A recent study determined the Illinois Agility test was suitable for evaluating agility performance in wheelchair rugby players (Usma-Alvarez, Ching Chua, Fuss, Subic, & Burton, 2011). However, wheelchair basketball players generally have more physical functional abilities when compared to wheelchair rugby players because rugby players have impairments in all four limbs, whereas the majority of wheelchair basketball players have only lower body impairments.

Thus, the purpose of this study was to determine the construct validity of the Illinois Agility test and the Williams Wheelchair Agility test (modified version of the T-test) for wheelchair basketball players. We hypothesized that agility test times would be faster for the elite compared to the competitive wheelchair basketball players.

Methodology

Participants

Twenty healthy wheelchair basketball players between the ages of 19 and 33 years volunteered to participate in this study that was approved by the local Institutional Review

Board. A priori power analysis using G*Power 3.1 revealed a sample size of n = 10 per group was sufficient to detect a large difference (1.2 SD) between groups for agility test time using a one-tailed t-test for independent samples at α=0.05 and statistical power of 0.8 (Faul, Erdelder, Lang, & Buchner, 2007). All potential local participants were recruited. Participants were grouped according to competition level (elite: n=7 vs. competitive: n=13); American National Wheelchair Basketball Association classification (NWBA) (high: n=9 vs. low: n=11); and sex (men: n=9 vs. women: n=11). A post hoc power analysis determined the group sizes were sufficient to detect moderate to large effect sizes (< .72 SD) using a one-tailed t-test for independent samples at α=0.05, with statistical power between 0.43-0.6; and large differences (1.2 SD) with a statistical power of .80.

The elite group inclusion criterion was defined as current National Team member (≥ 3 yrs experience), or current all-star status in the United States collegiate wheelchair league. Competitive players were defined as players currently playing on a United States collegiate wheelchair team, or players currently playing on a competitive club team with at least 2 years experience. The American National Wheelchair Basketball Association (NWBA) classification distribution of participants for the elite and competitive groups is listed in Table 2.1. Players are assigned a point value ranging from 1 (players with the least physical function; e.g. spinal cord injury, SCI) up to 4 (players with the highest physical function). Players are evaluated by certified experts on their ability to execute fundamental basketball movements: wheelchair propulsion (stops/starts, sprinting, turning), dribbling, shooting, passing, catching, rebounding, and reacting to contact. Tables 2.2 and 2.3 list participants' physical disabilities by category and individual characteristics.

Table 2.1 Distribution of participants based on NWBA classification and competition designation (n=20).

NWBA functional classification categories	Number of participants in each classification category	
	Elite	Competitive
1	1	5
2	2	3
3	2	2
4	2	3
Total	7	13

NWBA functional classification 1= least physical function
NWBA functional classification 4= highest physical function

Table 2.2 Participants' physical disabilities listed by category (n=20).

	Number of participants
Spinal cord injury	8
Lower-limb amputation	4
Spina bifida	2
Cerebral palsy	2
Other congenital or acquired conditions	3
Lower body impairment	1

Table 2.3 Participant characteristics with respect to sex, sport experience prior to WB, WB experience, and highest level of WB competition (yrs) (n=20).

Sex	Sport experience prior to WB (Yes/No)	WB Experience (yrs)	Highest level of WB competition
Elite			
M	Yes	18	National
F	No	10	National
F	No	7	National
F	Yes	8	National
F	No	7	National
F	Yes	6	National

F	No	11	National
Competitive			
M	No	14	Collegiate
M	No	9	Collegiate
M	No	4	Collegiate
M	Yes	12	Collegiate
M	Yes	3	Collegiate
M	No	12	Collegiate
M	Yes	5	Collegiate
M	Yes	8	Collegiate
F	No	12	Collegiate/National**
F	No	10	Collegiate
F	No	9	Collegiate
F	Yes	1	Collegiate
F	No	6	Collegiate/National*

WB= wheelchair basketball
* = 1 year National team experience
**=2 years National team experience

For a third criterion measure, two expert coaches were asked to independently rank each participant's agility skill using a visual analogue scale that used poor agility and superior agility as anchors at each end of the scale (100 mm). When reflecting on a player's agility skills, it was explained to the coaches that a superior agility rating indicated that that player was among the most agile players in the world (within that classification). Coaches were familiar with the participants but blinded to participants' agility and speed scores.

Testing Protocols and Procedures

Participants were tested in small groups on two separate days. Testing occurred in the morning from 6:00 to 8:00 am in an indoor gymnasium with hardwood floors [~ 23 °C, 30% – 50% relative humidity]. Participants used their own basketball wheelchairs for this study. During a single session participants performed 9 trials: 3 Illinois Agility trials, 3 Williams Wheelchair Agility trials, and 3 straight-line speed trials. The order of testing was counterbalanced by type of test. The first trial of each test was a familiarization trial. Scores were based on the average of trials 2 and 3. Construct validity was based on the premise that elite players would have significantly faster agility times than competitive players.

Upon arrival, testing protocols were explained to each participant and informed written consent was collected. Participants completed a 24-h history questionnaire to verify adherence to pre-test instructions: avoid the consumption of caffeine, alcohol, nonprescription drugs, and strenuous physical activity the day before and the day of testing. Tire pressure was verified and if it was lower than 758 kPa, additional air was added until pressure equaled at least 758 kPa.

Next, participants performed a 15-min warm-up, which consisted of a variety of pushing activities at graded intensities (light to 80-90% self-perceived maximum). After the warm-up, participants performed the Illinois Agility test, the Williams Wheelchair Agility test, and a straight-line speed test (counterbalanced order). A 2-min rest period was provided between trials and a 5-min rest period was provided between tests to ensure adequate recovery (Hutzler, Meckel, & Berzen, 2001). All participants were trained wheelchair basketball players and thus accustomed to the physical demands of the test trials. Participants were allowed to consume fluids at their discretion during the recovery periods. If requested, participants were given their test scores at the end of the session. Total session duration was approximately 1.5 hr for the women and 1 hr for the men.

Illinois Agility Test

The Illinois Agility Test course was 10 meters long and 10 meters wide (Figure 2.1). Infrared timing lights (Brower, Draper, Speedtrap II) were set-up 1.2 meters apart to mark the start and finish line gates. Cones were used to mark the turning points of the course; down the center of the course, an additional 4 cones were set-up 3.3 meters apart. Participants started from a stationary position with their front casters just behind the start line. The data recorder instructed participants to initiate the test at their own discretion. As soon as the participant crossed the start line, the timing gates were automatically activated and his/her trial time began. Participants were verbally encouraged to push as quickly as possible around the course in the direction indicated by study personnel, without displacing the cones. As soon as the participant crossed the finish line, the timing gates were deactivated, which automatically stopped the trial time. If a participant displaced a cone during the test, that time was discarded and the trial was repeated. The total number of attempts was tracked. Participants started on the right for their familiarization trial (Trial 1). Trial 2 was started on the right side and trial 3 from the left side.

Some participants had previous experience with this test (n=4). Three of the participants had completed this test once within the past 3 months of the current study. The other participant had completed this test once within the past year. It is not anticipated that their test times for this study were affected by previous experience with the test.

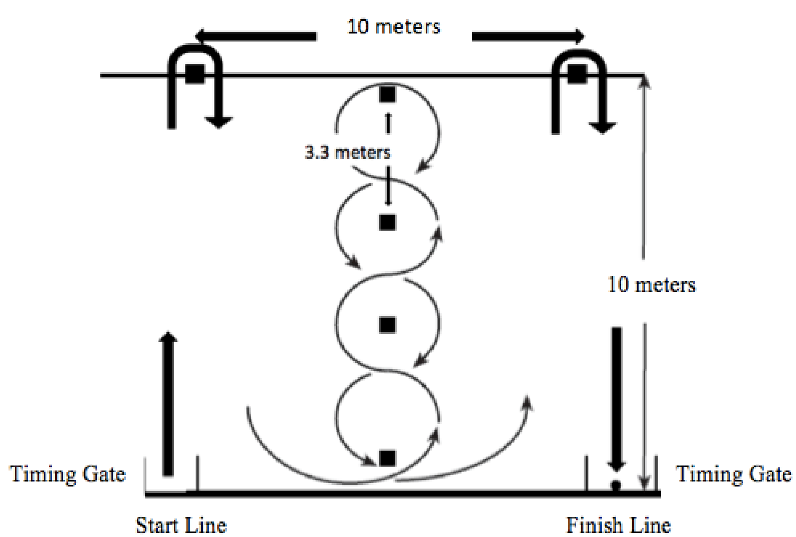

Figure 2.1. Illinois Agility Test set-up (modified from Davis et al., 2005).

Williams Wheelchair Agility Test

The Williams Wheelchair Agility test was developed based on the T-test originally created by Semenick (1990). The Williams Wheelchair Agility test protocols were created specifically for wheelchair basketball athletes. Participants started from a stationary position with their front casters just behind the start line A. The data recorder instructed participants to initiate the test at their own discretion. Participants were verbally encouraged to push as quickly as possible around the course in the direction indicated by study personnel, without displacing the cones. Cones were set-up 10 meters apart in the shape of the letter "T", with an additional 3 cones down the center of the course, 3.3 meters apart from each other. Participants started the test by weaving through the center cones. At the last cone, participants turned as quickly as possible and sprinted straight to line B. The participants had to come to a complete stop with their front casters across the taped line. Next, participants had to pull back twice, spin (180° pivot), and sprint straight across to line C. Again, participants had to come to a complete stop with their front casters across the taped line, followed by 2 backward pulls, a spin (180° pivot), and sprint back around the center cone.

After participants passed the center cone, they weaved back to the finish line as fast as possible (see Figure 2.2). As soon as the participant crossed the start/finish line, the timing gates were automatically activated (start) and deactivated (finish) (Brower, Draper, Speedtrap II). Participants completed the test once turning left first and once turning right first. If the participants did not cross the lines B & C with their front casters, the test was stopped and restarted. The total number of attempts was documented. This was a new agility test for wheelchair basketball; thus, none of the participants had any previous experience with this test.

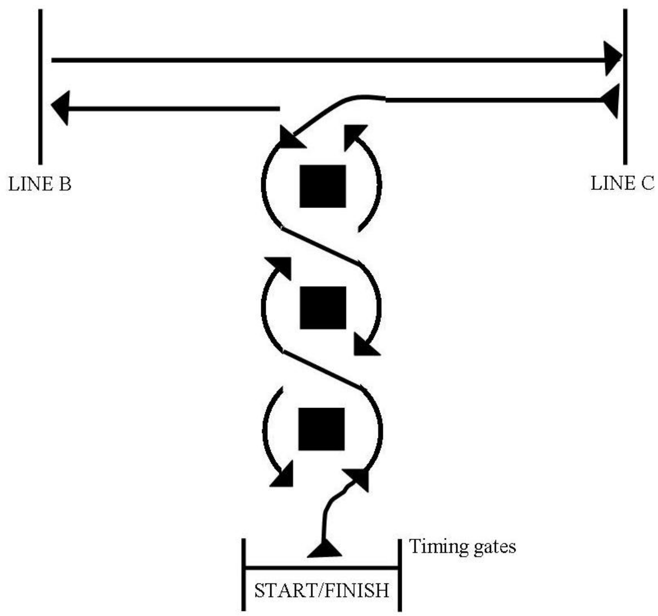

Figure 2.2. Williams Wheelchair Agility Test set-up.

Straight-line Speed Test

Participants started from a stationary position with their front casters just behind the start line (see Figure 2.3). The data recorder instructed participants to initiate the test at their own discretion. Participants were instructed to push 20-m as quickly as possible. Infrared timing gates were set-up at the start line, 5-m, and 20-m finish line. Trial time automatically starts when the front casters cross the start line and activates the timing gate and the trial time automatically stops when the front casters cross the finish line, which deactivates the timing gates. Both 5-m and 20-m times were recorded to the nearest 0.01 s.

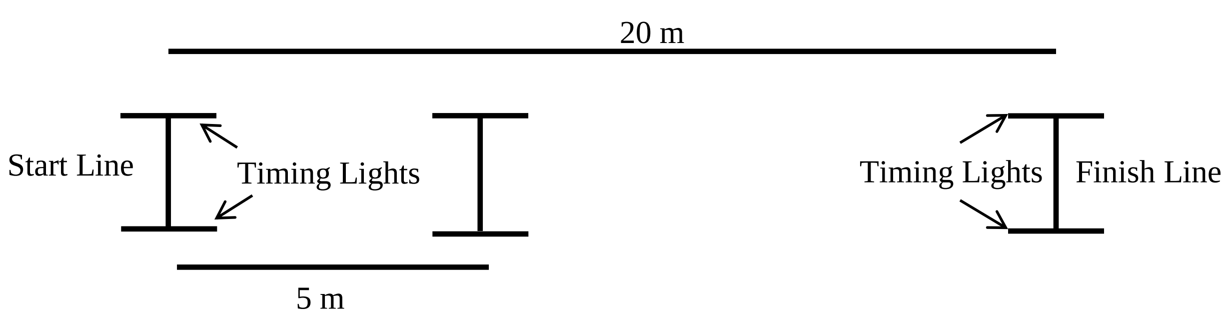

Figure 2.3 Straight-Line Sprint Test set-up.

Data Analyses

Independent t-tests and Fisher's exact tests were run to determine if there were any differences between the elite and competitive groups in terms of age, number of years playing wheelchair basketball, sport experience prior to disability/injury (years), on court training ($h \cdot wk^{-1}$), player functional classification high (NWBA classification 3 and 4) and low (NWBA classification 1 and 2), and sex. A Pearson correlation analysis was performed to determine the relationship between the coaches agility ratings compared to the agility and speed test scores.

Our primary purpose was to compare the elite players' agility times to the competitive players using independent t-tests (one-tailed). A test was considered to have demonstrated construct validity if mean times for elite players were significantly faster than mean times for competitive players. Secondary analysis compared high (NWBA classification 3 & 4) and low (NWBA classification 1 & 2) players' classification test times and male and female test times (independent one-tailed t-tests).

Reliability analyses started with a repeated-measures ANOVA between trials 2 and 3 for each agility test. The F ratio was used to evaluate trial effects and systematic error. When the effects for trials were non-significant ($p > .05$), intraclass correlation coefficient (ICC) and standard error of measurement (SEM) calculations were performed. For test-retest situations, Weir (2005) suggested using a 2-way fixed model for analyzing ICC (MS_S-MS_E /MS_S; where MS_E=error mean square; MS_S= subjects mean square). The SEM was estimated from the square root of the MS_E from the ANOVA table (Weir, 2005). Data are reported as mean ± SD unless otherwise noted. All hypothesis tests used an α level of .05. Statistical analyses were all performed using the Statistical Package for Social Sciences [SPSS; version 21.0, 2012, Chicago, IL]).

Results

Participants

Table 2.4 shows how similar the elite and competitive groups were with respect to age (elite: 24 ± 4 yrs; competitive: 22 ± 4 yrs, *p*=.32), sport experience prior to disability/injury (*p*=1.0), and wheelchair basketball experience (elite: 10 ± 4 yrs; competitive: 8 ± 4 yrs, *p*=.53). There was roughly an equal distribution of the higher classified participants between the elite and competitive groups. However, the majority of the lower classified participants and men were designated to the competitive group. A Fisher's exact test indicated there were no statistically significant differences between the elite and competitive groups regarding sex (*p*=.07) or classification (*p*=.64). However, the ratio of women to men was greater in the elite group and the NWBA functional classification means differed (Elite: 2.7; Competitive: 2.2). Self-reported on-court training times were also similar among participants (10-12 $h \cdot wk^{-1}$). Table 2.5 and 2.6 displays the similarities between participants when grouped by classification and by sex.

Table 2.4 Elite and competitive group characteristics with respect to sex, age (yrs; mean ± SD), classification, prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Sex		Age (yrs)	Classification		Prior sport experience		WB experience (yrs)
	M	W		High	Low	Yes	No	
Elite (n=7)	1	6	24 ± 4	4	3	3	4	10 ± 4
Competitive (n=13)	8	5	22 ± 4	5	8	5	8	8 ± 4
Total (n=20)	9	11	23 ± 4	9	11	8	12	9 ± 4

High=NWBA classifications 1 & 2; Low=NWBA classifications 3 & 4; WB = wheelchair basketball

Table 2.5 High and low classification group characteristics with respect to sex, age (yrs; mean ± SD), prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Sex		Age (yrs)	Prior sport experience		WB experience (yrs)
	M	W		Yes	N0	
Low (n=11)	5	6	22 ± 4	2	9	10 ± 4
High (n=9)	4	5	24 ± 3	6	3	7 ± 3
Total (n=20)	9	11	23 ± 4	8	12	9 ± 4

High=NWBA classifications 1 & 2; Low=NWBA classifications 3 & 4; WB = wheelchair basketball

Table 2.6 Men and women group characteristics with respect to age (yrs; mean ± SD), prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Age (yrs)	Prior sport experience		WB experience (yrs)
		Yes	N0	
Men (n=11)	24 ± 5	5	4	9 ± 5
Women (n=9)	22 ± 2	3	8	8 ± 3
Total (n=20)	23 ± 4	8	12	9 ± 4

WB = wheelchair basketball

Table 2.7 shows that the relationships between the speed test times and agility test times were strong. Also, Pearson correlations indicated that the coaches’ agility ratings were significantly associated with participants’ agility times more so than they were with speed times.

Table 2.7 Pearson correlation matrix of agility test times, speed times, and coaches' agility ratings (n=20).

	Williams	Illinois	5-m Speed	20-m Speed	Coach A	Coach B
Williams	-					
Illinois	.94*	-				
5-m Speed	.81*	.87*	-			
20-m Speed	.83*	.89*	.98*	-		
Coach A	-.68*	-.75*	-.57*	-.60*	-	
Coach B	-.78*	-.86*	-.64*	-.70*	.86*	-
Mean Coach Rating	-.77*	-.85*	-.63*	-.68*	.95*	.97*

*Significant at $P<.01$

Reliability

Repeated-measures ANOVA analyses indicated no systematic errors and intraclass correlations were above 0.9 for each test. Results are presented in Tables 2.8 and 2.9.

Table 2.8 ANOVA summary table for agility and speed tests.

	MS_S	MS_E	F	*p* value
Williams Agility Test	7.032	0.101	0.782	0.39
Illinois Agility Test	9.860	0.617	1.639	0.22
5-m Straight Line Speed	0.289	0.001	0.182	0.18
20-m Straight Line Speed	0.663	0.003	0.058	0.81

MS_S= subjects mean square; MS_E= error mean square

Table 2.9 Intraclass correlation coefficient (ICC) and standard error of measurement (SEM) for the agility and speed tests.

	ICC*	SEM (s)
Williams Agility Test	.94	0.32
Illinois Agility Test	.99	0.79
5-m Straight Line Speed	1.0	0.03
20-m Straight Line Speed	1.0	0.05

*ICC were all significant at *P*<.01.

Validity

Despite having similar straight-line speed, the elite group was significantly faster than the competitive group for both agility tests as illustrated in Figure 2.4 (Williams Agility test: 18.97 ± 0.53 s vs. 20.13 ± 2.22 s for elite and competitive groups, respectively, p=.048; Illinois Agility test: 26.34 ± 0.66 s vs. 27.95 ± 2.57 s for elite and competitive groups, respectively, p=.026).

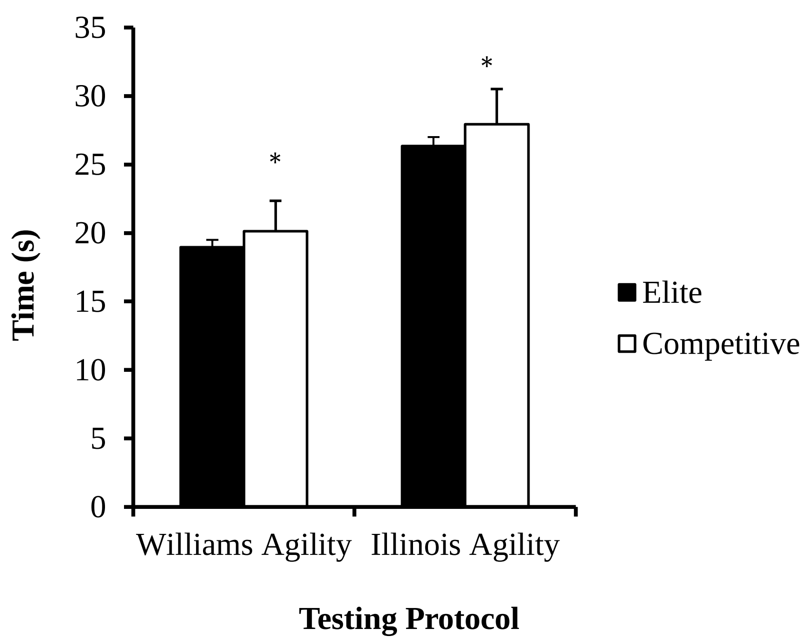

Figure 2.4 Elite (n=7) vs. Competitive (n=13) mean ± SD agility test times. *P<.05 between groups.

Secondary analyses indicate that the higher classified participants were more agile and faster than the lower classified participants (Williams Agility test: 18.86 ± 1.32 s vs. 20.43 ± 2.01 s for the high class and low class groups, respectively, *p*=.02; Illinois Agility test: 26.34 ± 1.23 s vs. 28.24 ± 2.52 s for the high class and low class groups, respectively, *p*=.02). Figure 2.5 displays the agility results and Figures 2.6 and 2.7 show the straight-line speed results for the high and low classification groups (5-m: 3.61 ± 0.30 s vs. 3.93 ± 0.39 s for the high class and low class groups, respectively, *p*=.03; 20-m: 5.52 ± 0.39 s vs. 6.04 ± .61 s for the high class and low class groups, respectively, *p*=.02) and for men and women (5-m: 3.53 ± 0.31 s vs. 4.00 ± 0.29 s for the men and women, respectively, *p*=.002; 20-m: 5.45 ± 0.41 s vs. 6.10 ± .54 s for the men and women, respectively, *p*=.004). It is interesting to note that there were no significant differences between men and women in regards to agility trial times, but men were faster than women in both 5-m and 20-m straight sprinting.

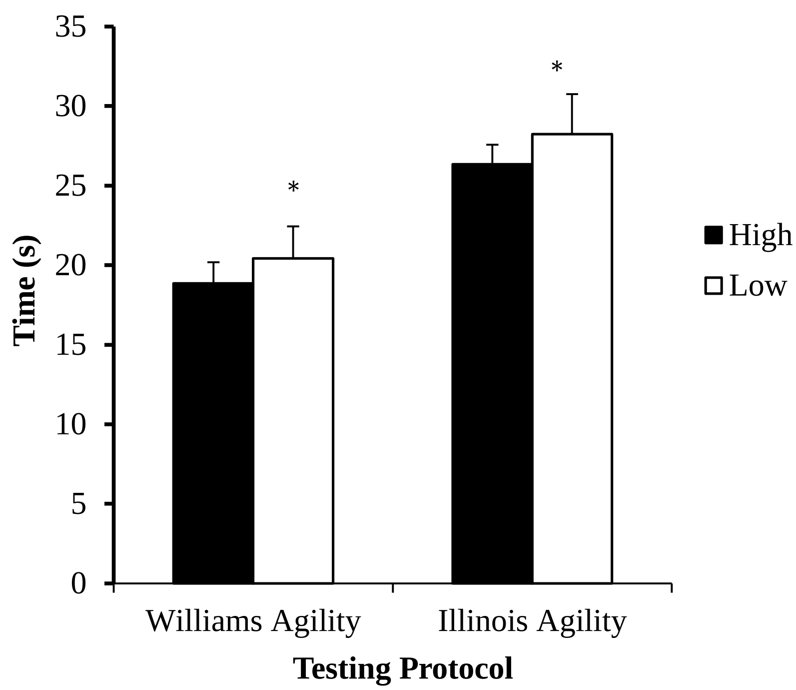

Figure 2.5 High (n=9) vs. Low (n=11) player classifications mean ± SD agility test times. High=NWBA classifications 1 & 2; Low=NWBA classifications 3 & 4; **P*<.05 between groups.

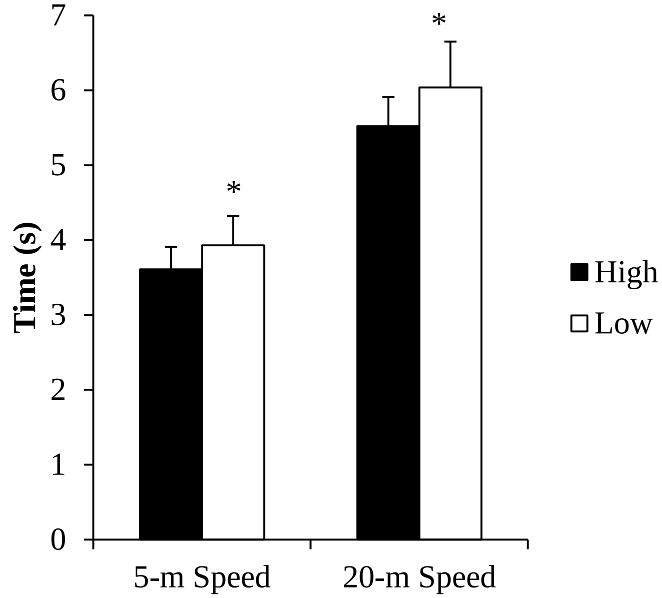

Figure 2.6 High=NWBA classifications 1 & 2 (n=9); Low= NWBA classifications 3 & 4 (n=11), mean ± SD straight-line 5-m and 20-m speed times,**P*<.05 between groups.

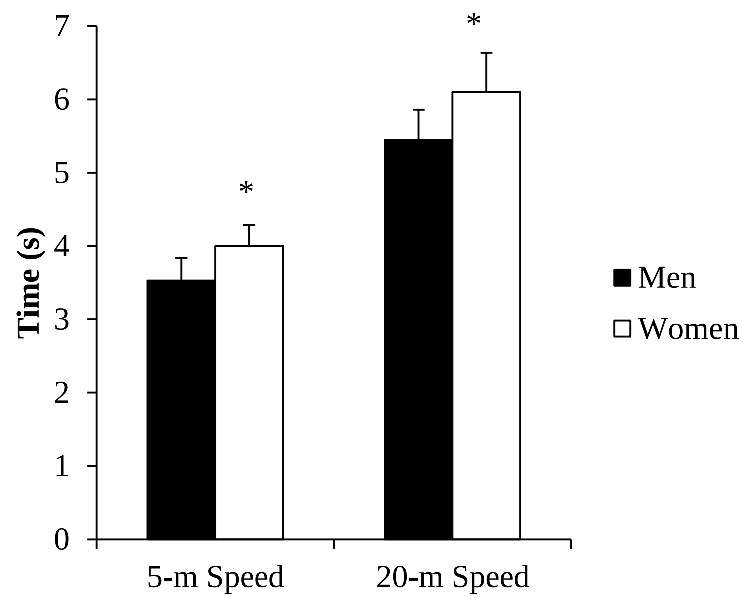

Figure 2.7 Men (n=9) vs. Women (n=11), mean ± SD straight-line 5-m and 20-m speed times, **P*<.05 between groups.

Discussion

The main finding from this study was that both agility tests demonstrated construct validity and thus, both may be effective in detecting agility. Both tests are planned agility tests that required participants to sprint, turn, and weave around cones in a pre-determined direction. However, there were some differences between the two tests as the Williams Wheelchair Agility test requires multiple starts and stops, backward propulsion, and 180 degree pivots. The Williams Wheelchair Agility test was also a shorter agility test to complete compared to the Illinois Agility test (Williams Agility test: 19.73 ± 1.88 s; Illinois Agility test: 27.39 ± 2.22 s). This is the first study attempting to determine the construct validity of the Williams Wheelchair Agility test and the Illinois Agility test for wheelchair basketball players.

As anticipated, men had significantly faster straight-line sprint times than women. We speculate that this is a result of men having stronger upper-body strength compared to women. Interestingly, despite the elite group being comprised mostly of women and the fact that women had slower straight-line speed times, the elite group had significantly faster agility times which suggests that sex was not a confounding factor.

In terms of NWBA classification, the higher class players (3 and 4) were significantly faster and more agile than the lower class players (1 and 2). Men and women were split approximately evenly between the two classification designations (Table 2.5). Thus, sex did not appear to explain why the higher classified players had faster straight-line sprint speed than the lower classified players. Again, strength may explain the difference in straight-line sprint speeds. We speculate that higher class players have the advantage of more core strength and trunk range of motion compared to lower class players, which could explain why higher class players had faster straight-line sprint speeds. This may also explain why the higher class players had faster agility times, as more core strength and range of motion would allow for maintaining higher speeds during the various turns of the agility courses and quicker starts and stops. Furthermore, 73% of the lower class players were in the competitive group. Thus, competition level may also partially explain why the higher class players were more agile than the lower class players since the elite group had faster agility times than the competitive group.

The straight-line sprinting segments in both of the planned agility courses may partially explain the high correlation with the speed tests. In previous studies, the slalom and the figure-8 test were also highly correlated with speed (r=0.80) (de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999). In addition, the agility ratings given by the expert coaches exhibited moderate to strong correlations with both agility tests, which is consistent with the findings from de Groot et al. (2012). Obviously, speed is important but after consideration of speed approximately 20% of the variance is still unexplained in the Illinois Agility test and 30% of the variance remains unexplained in the Williams Wheelchair Agility test. This suggests that the Williams Wheelchair Agility test may be more independent of speed. This also provides support for incorporating specific agility training into wheelchair basketball players' workouts.

The repeated-measures ANOVA summary (Table 2.5) suggests that there were no learning or fatigue effects and thus, the two-trial design for each test was sufficient. The ICC is considered an index of relative reliability (Weir 2005). The high ICC of both agility tests shows strong reliability in the context of this study. The SEM is believed to be a more practical measurement for coaches because individual athlete scores from repeated tests can be used to assess individual change (Weir, 2005). In the context of our study, SEM for repeated trials were small (within the 95% level of confidence), which suggests the tests were indeed reliable.

Limitations and recommendations

Due to the heterogeneous make-up of our sample, a larger sample size would have allowed for additional statistical analyses in terms of specific NWBA classification comparisons. Also, there are other factors believed to influence a wheelchair player's agility such as anthropometry, upper-body strength and power, and wheelchair configuration (Rice et al., 2011;

Vanlandewijck et al., 2001). Additional studies that take into account these potentially confounding factors could help in the evaluation of the validity of the Illinois and Williams Agility tests for wheelchair basketball players.

With a larger sample, it would also be interesting to compare players in terms of position/role on the team (e.g. are the top scorers the most agile players on a team?). For example, a recently published study ran a performance analysis of elite men's and women's wheelchair basketball teams (Gomez, Perez, Molik, Szyman, & Sampaio, 2014). From the variables investigated, it was concluded that field-goal percentage and free-throw rate were the most important factors in men's games, and field-goal percentage and offensive rebounding percentage in the women's game.

Another focus area is agility training, as both the Illinois and Williams Wheelchair Agility tests have demonstrated good reliability and construct validity in terms of measuring agility for wheelchair basketball players. Future wheelchair agility studies should also consider validating tests for the specific skills deemed important for optimal agility performance: acceleration, deceleration, pivoting, turning, forward and backward propulsion, and changes of direction.

Conclusion

This study found that both the Williams Wheelchair Agility test and the Illinois Agility test demonstrated construct validity and thus, both may be effective in assessing agility in wheelchair basketball players. Due to the potentially significant impact agility has on wheelchair basketball performance, more studies focusing on wheelchair basketball agility are warranted. It should be appreciated that after consideration of speed a large portion of the variance in agility is left unexplained. These will increase our current understanding of this complex skill and how to measure it.

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CHAPTER 3

VALIDATION OF A REACTIVE AGILITY TEST FOR WHEELCHAIR ATHLETES

Introduction

Agility or planned agility refers to the ability to rapidly change direction with no external stimulus (Farrow, Young, & Bruce, 2005; Gabbett, Sheppard, Pritchard-Peschek, Leveritt, & Aldred, 2008; Sheppard & Young, 2006). Planned agility is classified as a closed skill, as the exact movement pattern is known. However, during a wheelchair basketball game, optimal agility often depends on a response to a stimulus (ball, teammate, or opponent). This form of agility is unplanned because it requires a change of direction in response to an external stimulus, and is referred to as reactive agility (Young, James, & Montgomery, 2002). Reactive agility is classified as an open skill (Young et al., 2002) and consists not only of the commonly recognizable physical components (e.g. change of direction), but also of perceptual and decision-making components (e.g. cognitive skills) (Farrow et al., 2005).

Even though a wide variety of wheelchair basketball field tests are currently in use, very little has been published on this topic. All of the wheelchair basketball studies that have included an agility component have used planned agility tests (Brasile, 1986, 1990; de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999). These studies have used a slalom test or variations of a figure-8 test with and without a basketball as part of larger skill proficiency test batteries. Both of these tests are highly correlated with speed ($r \geq 0.80$) (de Groot et al., 2012; Vanlandewijck et al., 1999), which may be related to agility.

The slalom test used in the de Groot et al. (2012) study distinguished premier league players from competitive recreational league players. However, shortcomings of tests such as these are that they do not include all of the agility skills typically used in a wheelchair basketball game such as quick stops and starts or reacting to a stimulus.

Video reactive agility tests have been developed in an attempt to measure the cognitive component of agility (reactive agility). For example, a sport specific cue (e.g. a pass projected onto a screen) requires a player to process visual information and react appropriately. Video reactive agility tests differ from reactive agility tests in that video reactive agility tests feature a video projection of a player doing a sport-specific skill while reactive agility tests feature a generic stimulus (e.g. light, sound). Whereas there are some reactive agility tests currently used to test wheelchair basketball players, to the best of our knowledge, there are no reports in the scientific literature regarding their validity.

Therefore, the purpose of this study was to determine the construct validity of a video reactive agility test for wheelchair basketball players. We hypothesized that reactive agility test times would be shorter for elite compared to competitive wheelchair basketball players.

Methodology

Participants

Twenty healthy wheelchair basketball players between the ages of 19 and 33 years volunteered to participate in this study that was approved by the local Institutional Review Board. Participants were grouped according to competition level (elite vs. competitive). A priori power analysis using G*Power 3.1 revealed a sample size of n = 10 per group was sufficient to detect a large difference (1.2 SD) between groups for agility test time using a one-tailed t-test for independent samples at α=0.05 and statistical power of 0.8 (Faul, Erdelder, Lang, & Buchner, 2007). All potential local participants were recruited. Participants were grouped according to competition level (elite: n=7 vs. competitive: n=13); American National Wheelchair Basketball Association classification (NWBA) (high: n=9 vs. low: n=11); and sex (men: n=9 vs. women: n=11). A post hoc power analysis determined the group sizes were sufficient to detect moderate to large effect sizes ($< .72$ SD) using a one-tailed t-test for independent samples at $\alpha=0.05$, with statistical power between 0.43-0.6; and large differences (1.2 SD) with a statistical power of .80.

The elite group inclusion criterion was defined as current National Team member (≥ 3 yrs experience), and current all-star status in the United States collegiate wheelchair league. Competitive players were defined as players currently playing on a United States collegiate wheelchair team, or players currently playing on a competitive club team with at least 2 years experience. The American National Wheelchair Basketball Association (NWBA) classification distribution of participants for the elite and competitive groups is listed in Table 3.1. Players are assigned a point value ranging from 1 (players with the least physical function; e.g. SCI) up to 4 (players with the highest physical function). Players are evaluated by certified experts on their ability to execute fundamental basketball movements: wheelchair propulsion (stops/starts, sprinting, turning), dribbling, shooting, passing, catching, rebounding, and reacting to contact. Tables 3.2 and 3.3 list participants' physical disabilities by category and individual characteristics.

Table 3.1 Distribution of participants based on NWBA classification and competition designation (n=20).

NWBA functional classification categories	Number of participants in each classification category: Elite	Competitive
1	1	5
2	2	3
3	2	2
4	2	3
Total	7	13

NWBA functional classification 1=least physical function; NWBA functional classification 4=highest physical function

Table 3.2 Participants' physical disabilities listed by category (n=20).

Category	Number of participants
Spinal cord injury	8
Lower-limb amputation	4
Spina bifida	2
Cerebral palsy	2
Other congenital or acquired conditions	3
Lower body impairment	1

Table 3.3 Participant characteristics with respect to sex, sport experience prior to WB, WB experience, and highest level of WB competition.

Sex	Sport experience prior to WB (Yes/No)	WB Experience (yrs)	Highest level of WB competition
Elite			
M	Yes	18	National
F	No	10	National
F	No	7	National
F	Yes	8	National
F	No	7	National
F	Yes	6	National
F	No	11	National

Competitive			
M	No	14	Collegiate
M	No	9	Collegiate
M	No	4	Collegiate
M	Yes	12	Collegiate
M	Yes	3	Collegiate
M	No	12	Collegiate
M	Yes	5	Collegiate
M	Yes	8	Collegiate
F	No	12	Collegiate/National**
F	No	10	Collegiate
F	No	9	Collegiate
F	Yes	1	Collegiate
F	No	6	Collegiate/National*

WB= wheelchair basketball; *=1 year National team experience; **=2 years National team experience

Testing Protocols and Procedures

Participants were tested in small groups (2 or 3 participants at a time) on three separate occasions. Testing occurred in the morning from 6:00 to 8:00 am in an indoor gymnasium with hardwood floors [~ 23 °C, 30% – 50% relative humidity]. Participants used their own basketball wheelchairs for this study. During a single session participants completed 6 trials, which included 2 practice/familiarization trials and 4 performance trials (2 turning left and 2 turning right). Participants were blinded to each other's performances. While waiting, participants had their backs toward the testing area and thus could not watch one another. Construct validity was based on the premise that elite players possess greater reactive agility than competitive players, and therefore would have faster reactive agility test times.

Upon arrival, testing protocols were explained to each participant and informed written consent was collected. Participants completed a 24-h history questionnaire to verify adherence to pre-test instructions: avoid the consumption of caffeine, alcohol, nonprescription drugs, and strenuous physical activity the day before and the day of testing. Tire pressure was verified and if it was lower than 758 kPa, additional air was added until pressure equaled at least 758 kPa.

Next, participants performed a 15-min warm-up, which consisted of a variety of pushing activities at graded intensities (light to 80-90% self-perceived maximum). After the warm-up, individuals completed the video reactive agility test according to the protocol descriptions below. A single agility test trial required approximately 6-10 s to complete. Participants were given a 2-min rest period between trials to ensure adequate recovery (Hutzler, Meckel, & Berzen, 2001). All participants were trained wheelchair basketball players and thus accustomed to the physical demands of the test trials. Participants were allowed to consume fluids at their discretion during recovery times. If requested, participants were given their test scores at the end of the session. Total session duration was approximately 1 hr.

Video Reactive Agility Test

Participants started from a stationary position with their front casters just behind the start line at Gate 1. Figure 3.1 illustrates the video reactive agility course. The data recorder instructed participants to initiate the test at their own discretion. Participants were told to cross the start line and then come to a complete stop just behind the marked line at Gate 2 while looking at the video projection area. As soon as participants crossed the start line at Gate 1, the timing lights were automatically triggered and the trial time started (Brower, Draper, Speedtrap II). The timing lights beeped when they started. The primary investigator started playing the video stimulus as soon as she heard the beep (using a laptop connected to a video projector). The primary investigator was also watching for when the participants crossed the start line. The stimulus was a pre-recorded video of a wheelchair basketball player dribbling and throwing a pass, similar to what is seen in a wheelchair basketball game. The participants were required to make a decision and react as fast as possible pushing either left or right (a 30-45° change of direction) in response to the video stimulus. As soon as the participant crossed the marked line at Gate 2, a split time was recorded (decision time). The test ended when the participant crossed the finish line at either exit Gate 3 or 4 (Brower, Draper, Speedtrap II). All timing gates were 1.5 meters wide. A total of three different times were recorded: decision time, movement time, and reactive agility time. Decision time was the elapsed time from stimulus presentation to the first definitive movement the participant made in response to the video (crossing the marked line at timing Gate 2). Movement time was the time from when the participant crossed the marked line at timing Gate 2, to when they crossed through one of the exit gates. Reactive agility time (total trial time) began when participants crossed the start line at Gate 1 and ended when they crossed through one of the exit gates. Participants saw the same four video clips but in a counterbalanced order. Once a participant crossed the finish line, she/he was asked to push back lightly to the starting area. The participants were instructed to emphasize accuracy and speed. If a participant crossed the marked line at Gate 2 before the video stimulus was shown or anticipated incorrectly (guessed) and went the wrong way, the test was stopped and restarted. The total number of attempts was recorded. This was a new test of reactive agility, thus none of the participants had any previous experience with it.

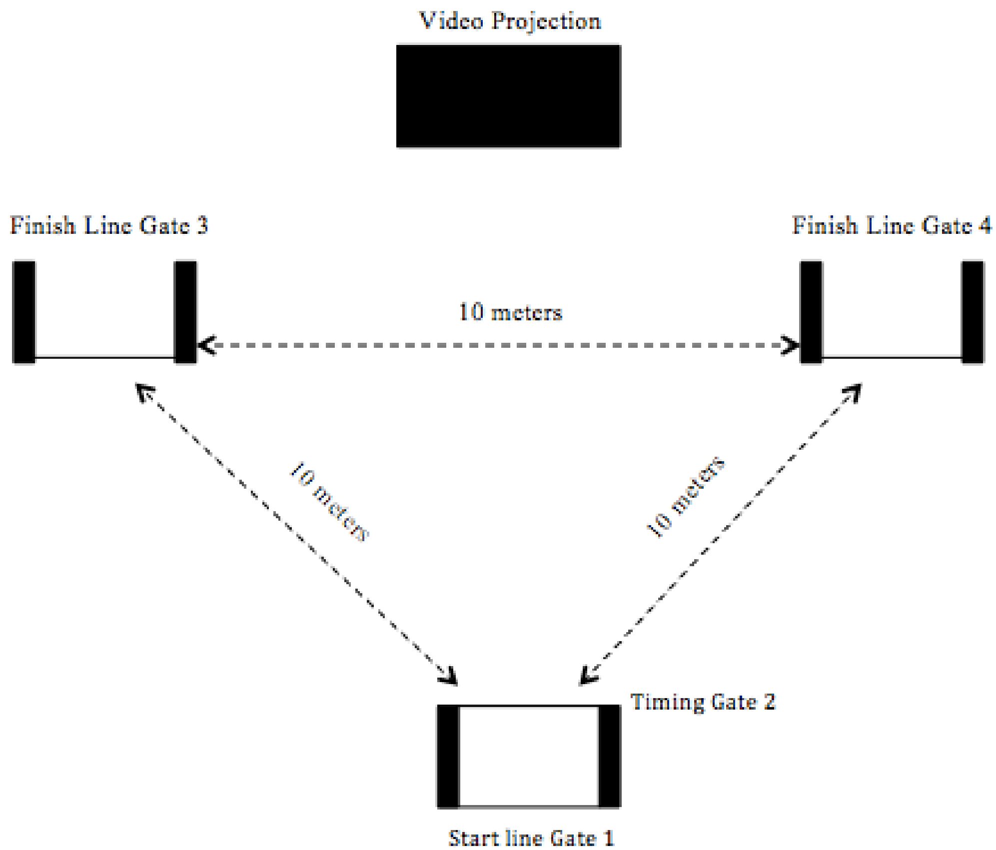

Figure 3.1 Video Reactive Agility Test set-up.

Data Analyses

Independent-t tests and Fisher's exact tests were used to analyze differences between the elite and competitive groups in terms of age, number of years playing wheelchair basketball, sport experience prior to disability/injury (years), on court training ($h \cdot wk^{-1}$), NWBA player classification, and sex. A Pearson correlation analysis was performed to determine if there was a relationship between reactive agility, planned agility, and speed with data collected from a previous study (within 2 weeks) using the same participants (Williams et al., unpublished data 2013).

Our primary purpose was to compare the elite players' video reactive agility times to those obtained by the competitive players using independent t-tests (one-tailed). The video reactive test was considered to have demonstrated construct validity if the mean times for elite players were significantly faster than mean times for competitive players. Secondary analyses compared high (NWBA classification 3 & 4) and low (NWBA classification 1 & 2) players' classification test times and men's and women's test times (independent one-tailed t-tests).

Reliability analyses started with a repeated-measure ANOVA between trials 3-6 for each of the time categories. The F ratio was used to evaluate trial effects and systematic error. When the effects for trials were non-significant ($p > 0.05$), intraclass correlation coefficient (ICC) and standard error measurement (SEM) calculations were performed. For test-retest situations, Weir (2005) suggested using a 2-way fixed model for analyzing ICC (MS_S- MS_E /MS_S; where MS_E=error mean square; MS_S=subjects mean square). The SEM was estimated from the square root of the MS_E from the ANOVA table (Weir, 2005). Data are reported as mean ± SD unless otherwise noted. All hypothesis tests used an α level of .05. Statistical analyses were all performed using the Statistical Package for Social Sciences [SPSS; version 21.0, 2012, Chicago, IL]).

Results

Participants

Table 3.4 shows how similar the elite and competitive groups were with respect to age (elite: 24 ± 4 yrs; competitive: 22 ± 4 yrs, *p*=.32), sport experience prior to disability/injury (*p*=1.0), and wheelchair basketball experience (elite: 10 ± 4 yrs; competitive: 8 ± 4 yrs, *p*=.53). There was roughly an equal distribution of the higher classified participants between the elite and competitive groups. However, the majority of the lower classified participants and males were designated to the competitive group. A Fisher's exact test indicated there were no statistically significant differences between the elite and competitive groups regarding sex (p=.07) or classification (p=.64). However, the ratio of women to men was greater in the elite group and the NWBA functional classification means differed (Elite: 2.7; Competitive: 2.2). Self-reported on-court training times were also similar among participants (10-12 $h \cdot wk^{-1}$). Table 3.5 and 3.6 display the similarities between participants when grouped by classification and by sex. A correlation summary is presented in Table 3.7.

Table 3.4 Elite and competitive characteristics with respect to sex, age (yrs; mean ± SD), classification, prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Sex		Age (yrs)	Classification		Prior sport experience		WB experience (yrs)
	M	W		High	Low	Yes	No	
Elite (n=7)	1	6	24 (±4)	4	3	3	4	10 (±4)
Competitive (n=13)	8	5	22 (±4)	5	8	5	8	8 (±4)
Total (n=20)	9	11	23 (±4)	9	11	8	12	9 (±4)

High=NWBA classifications 1 & 2; Low=NWBA classifications 3 & 4; WB= wheelchair basketball.

Table 3.5 High and low classification group characteristics with respect to sex, age (yrs; mean ± SD), prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Sex		Age (yrs)	Prior sport experience		WB experience (yrs)
	M	W		Yes	N0	
Low (n=11)	5	6	22 ± 4	2	9	10 ± 4
High (n=9)	4	5	24 ± 3	6	3	7 ± 3
Total (n=20)	9	11	23 ± 4	8	12	9 ± 4

High=NWBA classifications 1 & 2; Low=NWBA classifications 3 & 4; WB = wheelchair basketball.

Table 3.6 Men and women group characteristics with respect to age (yrs; mean ± SD), prior sport experience, and wheelchair basketball experience (yrs; mean ± SD) (n=20).

	Age (yrs)	Prior sport experience		WB experience (yrs)
		Yes	N0	
Men (n=11)	24 ± 5	5	4	9 ± 5
Women (n=9)	22 ± 2	3	8	8 ± 3
Total (n=20)	23 ± 4	8	12	9 ± 4

WB = wheelchair basketball.

Table 3.7 Summary of Pearson correlation matrix between reactive agility (decision time, movement time, total time), planned agility, and speed (n=20).

	Decision Time	Movement Time	Total time
Decision Time	-		
Movement Time	.33	-	
Total Time	.76**	.86**	-
Williams Agility Test	.79**	.42	.71**
Illinois Agility Test	.78**	.53*	.78**
5- m Speed	.73*	.31	.61*
20-m Speed	.76*	.36	.64*

* Significant at $P<.05$; ** Significant at $P<.01$

Reliability

Repeated-measures ANOVA analyses indicated no systematic errors between trials as *p* values were all above 0.05. Intraclass correlations (ICC) were moderate to strong for every time category. Results are presented in Tables 3.8 and 3.9 respectively.

Table 3.8 ANOVA summary table for the video reactive agility trials.

	MS_S	MS_E	F	*p* value
Decision Time Left	0.104	0.004	0.022	0.89
Decision Time Right	0.091	0.008	0.530	0.48
Movement Time Left	0.172	0.056	0.932	0.35
Movement Time Right	0.156	0.031	0.023	0.88
Total Time Left	0.343	0.046	1.216	0.28
Total Time Right	0.296	0.021	0.047	0.83

MS_S=subjects mean square; MS_E=error mean square

Table 3.9 Intraclass correlation coefficients (ICC) and standard error of the measurement (SEM) for the video reactive agility trials.

	ICC*	SEM (s)
Decision Time Left	.96	0.06
Decision Time Right	.92	0.09
Movement Time Left	.68	0.24
Movement Time Right	.81	0.18
Total Time Left	.86	0.21
Total Time Right	.93	0.15

*ICC were all significant at $P<.01$.

Validity

Figure 3.2 shows that the elite group had the fastest video reactive agility (decision, movement, and total reactive time) compared to the competitive group.

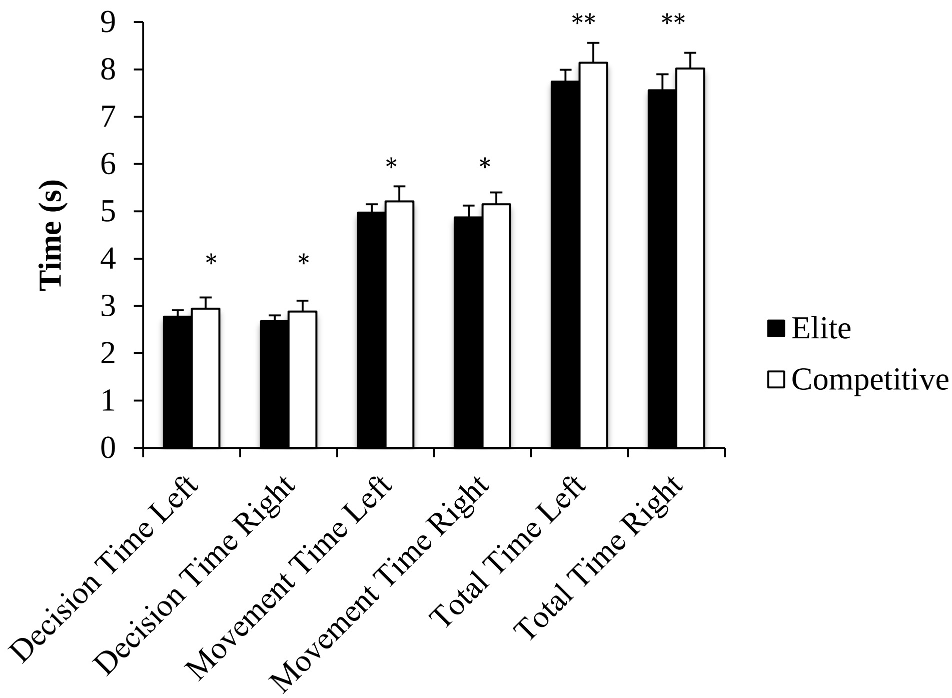

Figure 3.2 Elite vs. Competitive mean ± SD reactive agility decision, movement, and total reactive agility times (TT). *Significant at *P*<.05; **Significant at *P*<.01.

When participants were grouped by NWBA classification, the higher classified participants were significantly faster than the lower classified participants pushing to their right (Movement Time Right: 4.99 ± 0.15 s vs. 5.10 ± 0.35 s respectively, *p*=.02). There were no other significant differences between high and low classified participants. Men were also significantly faster than women when pushing to their right (Movement Time Right: 5.12 ± 0.40 s vs. 4.99 ± 0.11 s respectively, *p*=.02). There were no other significant differences between men and women.

All of the right handed participants' (n=18) mean movement times were faster pushing to their right compared to their left (Right: 5.10 ± .36; Left: 5.19 ± .30, *p*=.008). The majority of participants (n=18/20) required 4 attempts to complete their testing. The other two participants completed their testing in 5 attempts because they did not stop behind the line at Gate 2 and triggered the timing gate prematurely.

Discussion

The main finding of this study was that the video reactive agility test demonstrated construct validity as the elite group had the fastest video reactive agility trial times (decision, movement, and total reactive time) compared to the competitive group. This agility test required participants to react to a video stimulus (wheelchair basketball player passing a ball) and sprint a short distance. The major difference between this test and other agility tests reported in the wheelchair basketball literature (Brasile, 1986, 1990; de Groot, et al., 2012; Vanlandewijck, et al., 1999) is that the video reactive agility test is an open skilled test, where the other agility tests were closed skilled tests.

The perceived advantage of open skill testing over closed skill testing is an increase in ecological validity. More specifically, this includes consideration of the cognitive component in reactive agility. During a wheelchair basketball game, agility often depends on a response to a stimulus (ball, teammate, or opponent). As such, having valid, reliable, and feasible means for coaches to measure reactive agility is crucial. This study suggests that elite players have both superior physical (fastest movement times) as well as cognitive (fastest decision times) agility skills compared to competitive players.

It was somewhat surprising that speed was moderately correlated with total test time (5-m: r=.61; 20-m: r=.64) but not movement time. Since speed correlated with total test time, we would have anticipated that at least 5-m trial speed times would have also correlated with movement time (distance = 10-m).

Overall, decision time accounted for 76% of the variance in the total time for the video reactive agility test (p<.01) (Table 3.7). Similarly, movement time accounted for 86% of the variance in total test times (p<.01) (Table 3.7). This suggests that our simple method of performance analysis was able to measure 2 significant components of reactive agility: decision time (reactive) and movement time (speed). In addition, after consideration of planned agility, 20 to 30% of the variance of reactive agility is left unexplained (Illinois and Williams Agility tests, respectively).

The repeated-measures ANOVA summary (Table 3.8) suggests that there were no learning or fatigue effects and thus, the four-trial design for this test was sufficient. Guessing which direction to push did not appear to confound study results because none of participants went the wrong way during their trial attempts. The moderate to high ICCs of the different time categories of the video reactive agility test show strong reliability in the context of this study (Table 3.9). Furthermore, the SEM is believed to be a more practical measurement for coaches because individual athlete scores from repeated tests can be used to assess individual change (Weir, 2005). In the context of our study, SEMs for repeated trials were small (within the 95% level of confidence), which suggests the tests were indeed reliable.

Limitations

Due to the heterogeneous make-up of our sample, a larger sample size would likely have allowed for additional statistical analyses in terms of specific NWBA classification comparisons.

Furthermore, this study did not require the use of sophisticated technology, but this can be viewed as both a strength and limitation. It can be viewed as a strength because this study requires basic technology: timing lights, a laptop, and a projector, making it is easily reproducible. On the other hand, this basic set-up introduces human error, as the triggering of the video stimulus is not synced with the timing lights. A more advanced set-up would have the video projection and timing lights synced (eliminating human error).

Conclusion and recommendations

The primary finding of this study was that the video reactive agility test demonstrated construct validity and thus, appears effective in differentiating reactive agility in wheelchair basketball players. Due to the potentially significant impact reactive agility has on wheelchair basketball performance, more studies focusing on wheelchair basketball reactive agility are warranted. These will increase our current understanding of this complex skill and how to measure it.

Future studies may also want to investigate hand dominance and how it relates to reactive agility speed since all of the right handed participants (n=18) were faster pushing to their right compared to their left. It would also be interesting to compare players in terms of position/role on the team (e.g. are the top scorers the most agile players on a team?). For example, is there a relationship between a player's reactive agility and the number of steals or rebounds that player accumulates per game? Reactive agility training studies are another area that should be explored; specifically, the cognitive anticipatory component of agility needs further study.

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CHAPTER 4

FACTORS INFLUENCING AGILITY IN WHEELCHAIR BASKETBALL

Introduction

Success in wheelchair basketball is largely dependent on a player's ability to outmaneuver his/her opponent through the use of agility skills. Agility or planned agility refers to the ability to rapidly change direction with no external stimulus (Farrow, Young, & Bruce, 2005; Gabbett, Sheppard, Pritchard-Peschek, Leveritt, & Aldred, 2008; Sheppard & Young, 2006), while reactive agility refers to the ability to rapidly change direction in response to an external stimulus (ball, teammate, or opponent) (Young, James, & Montgomery, 2002). Reactive agility consists not only of commonly recognizable physical components (e.g. change of direction), but also of perceptual and decision-making components (e.g. cognitive skills) (Farrow et al., 2005).

There are many potential factors that may influence wheelchair agility, such as descriptive and anthropometric characteristics, upper-body strength and power, and propulsion technique (Rice et al., 2011; Vanlandewijck, Theisen, & Daly, 2001). Likewise, speed may also influence agility given that some performance tests are correlated with speed (de Groot, Balvers, Kouwenhoven, & Janssen, 2012; Vanlandewijck, Daly, & Theisen, 1999).

In addition to the aforementioned factors that may impact agility, wheelchair-user interface factors (i.e. wheelchair seat height, camber [the angle of the wheel in relation to the wheelchair frame], wheelbase length, and tire size) are also very important in wheelchair basketball and should be considered in relation to agility. The wheelchair-user interface refers to the interaction between the wheelchair and the user (Vanlandewijck et al., 2001). If a player is to reach his/her maximum functional ability on the basketball court, it is essential to optimize his/her wheelchair-user interface (Rice et al., 2011). In terms of agility, optimal chair set-up allows a player to rapidly change direction with a minimum reduction in speed because the player is able to maintain balance and power.

Currently, those factors most likely to influence agility in wheelchair basketball are speculative. Determining these factors would assist coaches in selecting players expected to be the most agile and inform training programs designed to increase agility. Thus, the purpose of this study was to determine if a wheelchair basketball player's athletic profile (i.e. descriptive variables, anthropometric variables, upper-body strength and power, and speed) and wheelchair configuration are related to planned agility, reactive agility, and speed. We hypothesized that planned agility and reactive agility are associated with:

1) Descriptive variables (age, previous sport experience, and number of years playing wheelchair basketball);
2) Anthropometric variables (height, bodyweight, skin fold thickness, body composition, trunk and arm length, and wrist and shoulder range of motion);
3) Upper-body strength, power, and speed;
4) Wheelchair configuration (seat height, camber, wheelbase length, tire size, and wheelchair mass).

Methodology

Participants

Twenty healthy wheelchair basketball players between the ages of 19 and 33 years volunteered to participate in this study that was approved by the local Institutional Review

Board. Participants were grouped according to competition level (elite vs. competitive). The elite group inclusion criterion was defined as current National Team member (≥ 3 yrs experience), and current all-star status in the United States collegiate wheelchair league. Competitive players were defined as players currently playing on a United States collegiate wheelchair team, or players currently playing on a competitive club team with at least 2 years experience. National Wheelchair Basketball Association (NWBA) functional classification category distribution of participants for the elite and competitive groups is listed in Table 4.1. Players are assigned a point value ranging from 1 (players with the least physical function; e.g. spinal cord injury (SCI)) up to 4 (players with the highest physical function). Players are evaluated by certified experts on their ability to execute fundamental basketball movements: wheelchair propulsion (stops/starts, sprinting, turning), dribbling, shooting, passing, catching, rebounding, and reacting to contact. Tables 4.2 and 4.3 list participants' physical disabilities by category and individual characteristics (respectively).

Table 4.1 Distribution of participants based on NWBA classification and competition designation (n=20).

	Number of participants in each classification category	
NWBA functional classification categories	Elite	Competitive
1	1	5
2	2	3
3	2	2
4	2	3
Total	7	13

NWBA functional classification 1=least physical function; NWBA functional classification 4=highest physical function

Table 4.2 Participants' physical disabilities listed by category (n=20).

Category	Number of participants
Spinal cord injury	8
Lower-limb amputation	4
Spina bifida	2
Cerebral palsy	2
Other congenital or acquired conditions	3
Lower body impairment	1

Table 4.3 Participant characteristics with respect to sex, sport experience prior to WB, WB experience, and highest level of WB competition (n=20).

Sex	Sport experience prior to WB (Yes/No)	WB Experience (yrs)	Highest level of WB competition
Elite			
M	Yes	18	National
F	No	10	National
F	No	7	National
F	Yes	8	National
F	No	7	National
F	Yes	6	National
F	No	11	National
Competitive			
M	No	14	Collegiate
M	No	9	Collegiate
M	No	4	Collegiate
M	Yes	12	Collegiate
M	Yes	3	Collegiate
M	No	12	Collegiate
M	Yes	5	Collegiate
M	Yes	8	Collegiate
F	No	12	Collegiate/National**

F	No	10	Collegiate
F	No	9	Collegiate
F	Yes	1	Collegiate
F	No	6	Collegiate/National*

WB= wheelchair basketball; * = 1 year National team experience; ** = 2 years National team experience

Testing Protocols and Procedures

This study consisted of 2 sessions during which anthropometric, body composition [air displacement plethysmography (Bodpod)] and skinfold thickness at 6 sites, upper-body strength and power, shoulder and wrist range of motion, and wheelchair configuration measurements, were taken. Each session took approximately 1 hour to complete. The agility and speed data used in this study were collected in a previous research project using the Illinois Agility test, Williams Wheelchair Agility test, and a video reactive agility test (Williams, Wingo & Richardson, 2013 not published). The agility and speed data were collected no more than 2 weeks prior to this study and used the same participants.

Session 1

All testing occurred in a temperate environment (~ 23 °C, 30% – 50% relative humidity). Participants reported to the Student Recreation Center at the University of Alabama. Trials were completed in the early morning, thus subjects were allowed to consume a light breakfast before arrival. Upon arrival, testing protocols were explained to each participant and informed written consent was collected. Participants completed a 24-h history questionnaire to verify adherence to pre-test instructions: avoid the consumption of caffeine, alcohol, nonprescription drugs, and strenuous physical activity the day before and the day of testing.

Weight (kg), height (cm), waist girth (cm), body mass index (BMI), skinfold thicknesses at 6 sites (mm) and body composition (via air displacement plethysmography) were measured by the same 3 trained study personnel. Skinfold measurements were taken with calipers (Lange, Beta Technology Incorporated, Cambridge, Maryland) from the following sites: triceps, subscapular, suprailiac, abdomen, thigh, and calf. The 6 sites were divided into 2 groups for data analyses. The first group comprised of triceps, suprailiac, subscapular, and calf because Sutton et al. (2009) recommends using the modified Withers et al. (1987) body density equation for estimating percentage of body fat in wheelchair athletes. The second group comprised of triceps, abdomen, and thigh because Mojahedi et al. (2009) suggests using Evans et al. (2005) body density equation for estimating percentage of body fat in wheelchair athletes. Whenever possible, participants (n=18) were landmarked on the right side of the body as per American College of Sports Medicine (ACSM) guidelines (ACSM, 2010). One participant's lower body was landmarked on their left side because of their amputation, the other participant was a double amputee. Data were recorded in millimeters. The mean of 2 measurements was used for data analysis. If the two measurements differed more than 2 mm, a third measurement was done and the average of the 2 closest measurements was used for data analysis (ACSM, 2010).

As there are no criterion prediction equations for estimating percentage of body fat from skinfold measurements for individuals with a disability, absolute values were used in the data analyses. Body mass index (BMI) was calculated from mass and height.

Session 2

The second session took place under the same conditions as session 1. Participants warmed-up for 15 min with a variety of pushing activities at graded intensities (light to 80-90% self-perceived maximum). After the warm-up, participants rotated through 5 stations in the following order:

Station 1: Grip Strength (Procedure adapted from Sale 1991):

1. Participants were seated in their basketball wheelchair with their head facing straight ahead and their arms at their side.
2. The participant's elbow was allowed to be at any angle between 90° and 180° (from a right angle to straight) at the side of the body.
3. The participant's wrist and forearm were in a midprone position.
4. The participants were asked to squeeze the (PC 5030J1, Jamar, Boling Brook, IL) hydraulic hand dynamometer maximally following these instructions:
   "Are you ready?", followed by "Squeeze as hard as you can". As the participant began to squeeze, the following instructions were given: "Harder!...Harder!...Relax"
5. The participant completed 2 trials with each hand (alternating hands after each trial), with at least 30-60 s rest between trials for the same hand.
6. The best score from each hand were added together to give total grip strength scores (kg). Total grip strength scores were used for analyses.
7. Study personnel ensured the dynamometer was reset to zero after each trial.

Station 2: Medicine ball toss

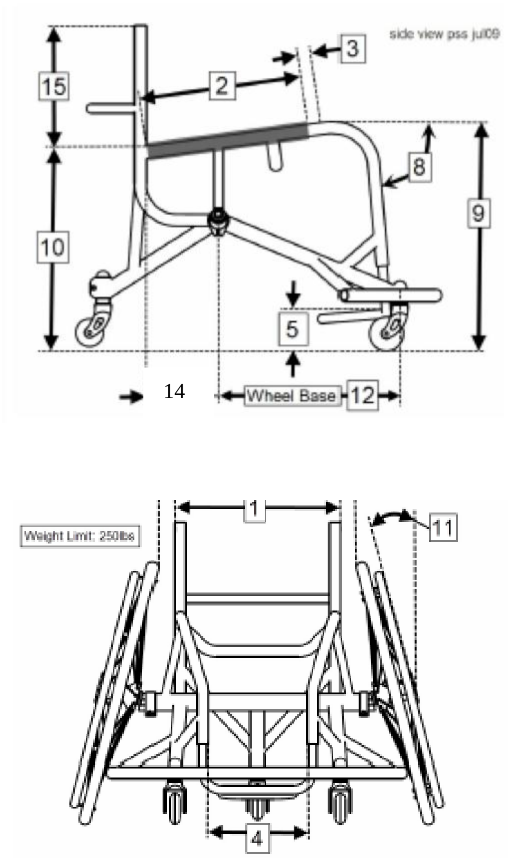
Participants were seated and strapped into their basketball wheelchair with their front and back casters blocked with weights to stabilize the wheelchair so it did not move during the medicine ball toss. Participants started with their backs in contact with the backrest of their wheelchair. Study personnel instructed participants to hold the medicine ball with their hands on either side of the ball, similar to the start of a chest pass. Their forearms were positioned parallel to the ground. A 4-kg medicine ball was used. Participants were instructed to throw the medicine ball, using a chest past, as far and straight as possible. The participant's back did not have to remain against their backrest. The distance where the ball hit the floor first was recorded to the nearest cm. A tape measure was secured to the floor starting from the front casters. The best result of 3 throws was used in data analysis. Participants had 2 min of rest between each throw and were allowed 1 practice throw (total of 4 throws). This field test is frequently used to measure upper-body power in able bodied athletes (Clemons, Campbell, and Jeansonne 2010).

Station 3: Torso and arm length; Shoulder and wrist range of motion:

a. Torso and arm length: Procedures were adapted from Wang et al. (2005): Arm length was measured from the acromion to the most distal portion of the middle finger of both arms in the anatomical position with a flexible yet inelastic tape measure. Torso length was measured from the greater trochanter to the acromion while the participant was seated in his/her own wheelchair or desk chair. Participants were instructed to sit-up as straight as possible while taking a deep breath in and holding it for several seconds. Two measurements were taken. The average of the two measurements was recorded to the nearest tenth of a cm.
b. A plastic 360° goniometer was used to measure the range of motion (ROM) of the shoulder and wrist joints by a licensed Occupational Therapist. Procedures were adapted from Wang et al. (2005). Shoulder ROM included active flexion and extension. Wrist ROM included active flexion/extension and ulnar deviation because these are important joint actions during the push phase of wheelchair propulsion. The participant's dominant side was measured. Participants were measured while seated in their everyday wheelchair or while sitting on a desk chair.

Station 4: Wheelchair Dimension: Seat height, Camber, and Wheelbase Length

Participants' basketball wheelchairs were measured as followed (participants were not in their chairs while measurements were taken):



- Seat height was measured in centimeters from the floor to the top of the players cushion (9).
- Front wheelbase length was measured in centimeters from the front caster to center of the camber bar (12).
- Back wheelbase length was measured from the front of the back post to the center of the camber bar (14).
- Camber was measured in degrees with a plastic 360° goniometer (11).

Figure 4.1 Wheelchair Diagram (adapted with permission from Invacare, 2014).

Station 5: 1 Repetition maximal bench press

The bench press was done using a standard free weight bench press bar (20.5 kg) and weights. Participants began by lying flat on the bench, with their feet flat on the floor or strapped comfortably to the bench. Their buttocks and shoulders were touching the bench with additional straps used as needed for stability. Participants were instructed to grasp the bar at a comfortable distance slightly wider than shoulder width. They started with their arms fully extended, holding the weight directly above their chest. The weight was lowered at a controlled speed until the bar touched their chest and then it was returned to the starting position.

A certified strength and conditioning specialist instructed and supervised participants for safety. A warm-up of 10 repetitions (reps) using a light-to-moderate weight was completed prior to testing. After a 2 min rest, a heavier warm-up set of 5 reps was completed. The participant then rested for 3 min before performing the first 1 rep max attempt using the lifting technique described above. If the lift was successful, participants rested for another 3 min before a second attempt was done at an increased load (5-10%). This sequence was repeated until the participant failed to perform the lift. Once failure was achieved, the participant rested for another 3 min and then attempted one more lift at a 2.5-5% lower weight. The final successful lift was considered their 1 rep max. All maximum lifts were completed within 5 or less attempts (after the warm-up sets) so fatigue did not impact participants' results. Participants were given verbal encouragement throughout the entire protocol. Failure was defined as the participant not being able to return the weight to the starting position (arms fully extended) (National Strength and Conditioning Association, 2009).

Participants were granted a minimum of 3 min of recovery between stations 1 and 2. All participants were experienced wheelchair basketball players and thus accustomed to the physical demands of the test trials. Fatigue was not anticipated to affect performance with the allotted recovery time between tests (Hutzler, Meckel, & Berzen, 2001). Participants were allowed to drink ad libitum between testing/measurements.

Data Analyses

To test the first hypothesis, a general linear model (multivariate) was used to determine if wheelchair planned agility, reactive agility, and speed were related to the following descriptive variables: age, previous sport experience, and number of years playing wheelchair basketball.

Separate stepwise linear regression analyses were run to test each of the following hypotheses:

2) wheelchair planned agility, reactive agility, and speed are related to the following variables:

2a) height, weight, percentage of fat and fat-free mass determined from air displacement plethysmography, and BMI;

2b) skinfold sites: triceps, suprailiac, subscapular, and calf

2c) skinfold sites: triceps, abdomen, and thigh.

2d) trunk and arm length;

2e) shoulder flexion, shoulder extension, wrist flexion, and ulnar deviation;

3) wheelchair planned agility, reactive agility, and speed are related to upper-body strength and power;

4) wheelchair planned agility, reactive agility, and speed are related to wheelchair configuration [seat height, camber (the angle of the wheel in relation to the wheelchair frame), wheelbase length and tire size].

Next, regression analyses were performed to determine overall models of best fit using all of the significantly correlated variables, as well as relative strength (defined as maximum bench press/body weight), for each agility and speed test.

Lastly, independent sample t-tests were used to analyze mean differences between elite vs. competitive players; high vs. low classification; and men vs. women players for all significant predictor variables. All significance tests used an α level of 0.05. Statistical analyses were performed using the Statistical Package for Social Sciences [SPSS; version 21.0, 2012, Chicago, IL]).

Results

Hypothesis 1

A general linear model analysis indicated no significant relationship between age, previous sport experience, and number of years playing wheelchair basketball with planned agility, reactive agility, or speed.

Hypothesis 2a

Table 4.4 indicates that percentages of fat mass and fat-free mass were significantly associated with planned agility and bodyweight was significantly associated with speed.

Table 4.4 Correlation between predictor variables (height, bodyweight, % of fat and fat-free mass, and BMI) and planned agility, reactive agility, and speed test trial times (n=20).

	Planned Agility		Reactive Agility		Speed	
Variables	Williams	Illinois	Movement Time	Total Time	5-m	20-m
Height	-.20	-.21	.09	.03	-.36	-.42
Bodyweight	-.19	-.16	-.11	-.11	-.46*	-.48*
% Fat Mass	.46*	.50*	.24	.36	.30	.24
% Fat-free Mass	-.46*	-.50*	-.24	-.36	-.30	-.24
BMI	.23	.27	-.05	.01	.18	.27

*Significant at *P*<.05.

As indicated by Table 4.5, percentage of fat mass was the only independent variable included in the stepwise regression model for both the Williams and Illinois agility tests. Our regression analyses indicated that none of the variables listed in Table 4.4 were significant predicators of reactive agility trial times.

Table 4.5 Summary of stepwise regression analyses predicting Williams Agility and Illinois Agility test performance from % fat mass (n=20).

Step 1	Williams Agility Test					Illinois Agility Test				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
% Fat Mass	.104	.048	.456	2.175*	.21	.134	.055	.497	2.427*	.25

Predictor variables entered: height, bodyweight, % of fat and fat-free mass, and BMI; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; Williams: F(1,18)= 4.733, *P*=.04; Illinois: F(1,18)=5.89, *p*=.03; *Significant at *P*<.05.

Both bodyweight and percentage of lean mass were independent predictors of speed (Table 4.6). Together they accounted for 47% of the variance in the 5-m speed test performance and 43% of the variance in the 20-m speed test performance.

Table 4.6 Summary of stepwise regression analyses for prediction of 5- and 20-m speed from body weight and % fat-free mass (n=20).

	5-m					20-m				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Body Weight	-.006	.003	-.457	-2.181*	.21	-.010	.004	-.479	-2.312*	.23
Step 2										
Body Weight	-.009	.003	-.663	-3.473**		-.014	.004	-.661	-3.351*	
% Fat-free Mass	-.025	.009	-.549	-2.872*	.47	-.034	.014	-.486	-2.463*	.43

Predictor variables entered: height, bodyweight, % of fat and fat-free mass, and BMI*;* *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; 5-m: F(2,17)=7.46, *p*=.01; 20-m: F(2,17)= 6.46, *p*=.01; *Significant at *P*<.05; **Significant at *P*<.01.

Hypothesis 2b

Regression analyses indicated that waist girth and the skinfold thickness at the triceps, suprailiac, subscapular, and calf were not significant predicators of planned agility or reactive agility trial times. Only waist girth was significantly related to 5-m and 20-m speed (Table 4.7), and thus, the only independent significant predictor of speed (Table 4.8).

Table 4.7 Correlations of skinfold thickness and waist girth with speed (n=18).

Variables	5-m	20-m
Triceps	.52	.50
Suprailiac	-.46	-.42
Subscapular	-.25	-.20
Calf	-.03	.06
Waist Girth	-.56*	-.62*

*Significant at *P*<.05.

Table 4.8 Summary of stepwise regression analysis predicting speed test trial times from waist girth (n=18).

	5-m					20-m				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Waist Girth	-.018	.007	-.552	-2.648*	.31	-.025	.010	-.529	-2.491*	.28

Predictor variables entered*:* triceps, suprailiac, subscapular, calf, and waist girth; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; 5-m: F(1,16)= 7.012, *p*=.02; 20-m: F(1,16)= 6.206, *p*=.02; *Significant at *P*<.05.

Hypothesis 2c

Regression analyses indicated that skinfold thickness at the triceps, abdomen, and thigh were not significant predicators of planned agility, reactive agility, or speed trial times.

Hypothesis 2d

Regression analyses indicated that trunk and arm length were not significant predictors of planned agility, reactive agility, or speed test trial times.

Hypothesis 2e

Regression analyses indicated that shoulder flexion, shoulder extension, wrist flexion, and ulnar deviation were not significant predicators of planned agility or speed test trial times. The results of the reactive agility regression analyses indicated that ulnar deviation was a significant predictor (Tables 4.9 & 4.10). However, the scatter plots illustrate the outliers may be skewing the results (Figures 4.2 & 4.3).

Table 4.9 Correlations of shoulder and wrist joint mobility with reactive agility (n=20).

Variables	Movement Time	Total Time
Shoulder Flexion	-.44	-.33
Shoulder Extension	-.20	-.33
Wrist Flexion	-.03	-.11
Ulnar Deviation	-.60**	-.52*

*Significant at *P*<.05; **Significant at *P*<.01.

Table 4.10 Summary of stepwise regression analyses predicting reactive agility from ulnar deviation (n=20).

	Movement Time					Total Time				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Ulnar Deviation	-.039	.012	-.597	-3.158*	.36	-.050	.019	-.518	-2.568*	.27

Predictor variables entered: shoulder flexion, extension, and wrist flexion and ulnar deviation; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; Movement: F(1,18)= 9.973, *p*= .005; Total Time: F(1,18)= 6.594, *p*= .02; *Significant at *P*<.05.

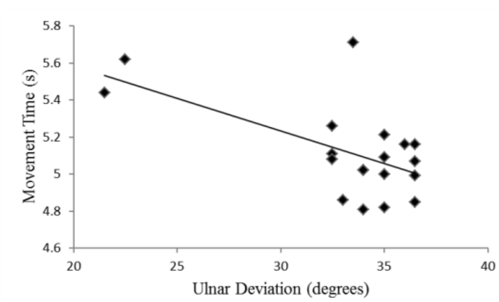


Figure 4.2 Relationship between Ulnar Deviation (degrees) and Movement Time (s); y=6.43+(-0.04x); R^2=.36; SEE=.23; n=20.

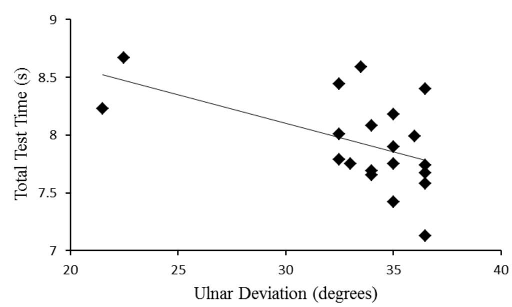


Figure 4.3 Relationship between Ulnar Deviation (degrees) and Total Test Time (s); y=9.59+(-0.05x); R^2=.27; SEE=.35; n=20.

Hypothesis 3

Table 4.11 displays the correlation results of 1-repetition maximum bench press, medicine ball toss, and grip strength variables as they relate to planned and reactive agility, and speed. Regression analyses indicated that only the medicine ball toss was an independent significant predicator of planned agility and speed (Tables 4.12 and 4.13).

Table 4.11 Correlation of 1-repetition maximum bench press, medicine ball toss, and grip strength variables with planned agility, reactive agility, and speed test trial times (n=19).

	Planned Agility		Reactive Agility		Speed	
	Williams	Illinois	Movement Time	Total Time	5 meters	20 meters
Max Bench	-.59**	-.63**	-.25	-.41*	-.80**	-.74**
Med Ball Toss	-.68**	-.67**	-.20	-.41*	-.84**	-.83**
Grip Strength	-.46	-.49	-.23	-.13	-.58**	-.54*

Bench press 1-repetition maximum n=19; Med ball toss n= 20; Grip strength n=20; *Significant at *P*<.05; **Significant at *P*<.01.

Table 4.12 Summary of stepwise regression analysis prediction of planned agility from medicine ball toss (n=19).

	Williams Agility Test					Illinois Agility Test				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Med Ball Toss	-.024	.006	-.675	-3.777*	.47	-.028	.008	-.667	-3.693*	.45

Predictor variables entered*:* 1-repetition maximum bench press, medicine ball toss, and grip strength; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; Williams: F(1,17)= 14.266, *p*=.002; Illinois: F(1,17)= 13.639, *p*=.002; *Significant at *P*<.01.

Table 4.13 Summary of stepwise regression analysis prediction of speed from medicine ball toss (n=19).

	5-m					20-m				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Med Ball Toss	- .007	.001	-.836	-6.277*	.70	-.011	.002	-.825	-6.022*	.68

Predictor variables entered*:* 1-repetition maximum bench press, medicine ball toss, and grip strength; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; 5-m: F(1,17)=39.404, *p*< .01; 20-m: F(1,17)= 36.264, *p*< .01; *Significant at *P*<.01.

Hypothesis 4

Regression analyses indicated that the following wheelchair configuration variables (seat height, camber [the angle of the wheel in relation to the wheelchair frame], wheelbase length, tire size, and wheelchair mass) were not significant predicators for any of the agility or speed tests. A summary of participants' wheelchair configuration measurements is presented in Table 4.14. Both seat height (r=.58, p=.008) and tire size (r=.49, p=.029) correlated with bodyweight. Seat height also correlated with the medicine ball toss (r=.45, p=.046). None of the other wheelchair measurements correlated with any of the other significant predictors.

Table 4.14 Summary of participants' wheelchair configuration measurements (n=20).

	Mean ± SD	Minimum	Maximum
Seat Height (cm)	52.01 ± 5.64	43.18	60.45
Camber (°)	16.50 ± 1.93	15	20
Front Wheelbase (cm)	43.62 ± 3.86	36.83	52.07
Rear Wheelbase (cm)	14.64 ± 2.10	10.16	18.42
Tire Size (cm)	63.50 ± 1.91	60.96	68.58
Wheelchair Mass (kg)	12.50 ± 0.99	10.66	14.97

Best Fit Model Analyses

Pearson correlation results showed relative strength to be moderately correlated with planned agility and speed (Table 4.15). Relative strength was added to the variable list because of the relationship between bodyweight and strength. Table 4.16 displays the correlation results of all the significant predictor variables.

Table 4.15 Correlation of relative strength with planned agility (Williams Agility Test and Illinois Agility Test), reactive agility (Movement Time and Total Test Time), and speed (n=19).

	Relative Strength
Williams Agility Test	-.51*
Illinois Agility Test	-.59*
Movement Time	-.11
Total Test Time	-.33
5-m Speed Test	-.72**
20-m Speed Test	-.63**

*Significant at *P*<.05; ** Significant at *P*<.01

An overall best fit model was created for both planned agility tests using the individual significant predictor variables (percentage of fat mass and medicine ball toss) and relative strength. Regression analyses indicated the medicine ball toss was the strongest independent predicator of planned agility as it was the only variable entered into the equation (Williams Agility r^2=.47; Illinois Agility r^2=.45). However, when speed test times (5-m and 20-m) were included in the regression analyses along with fat mass percent, medicine ball toss, and relative strength, 20-m speed was the strongest predictor for the Williams Wheelchair Agility test (Figure 4.3) and 20-m speed together with the medicine ball toss were the strongest predictors for the Illinois Agility Test (Table 4.17).

Table 4.16 Correlation of all the significant predictor variables (n=19).

	Body-weight	% Fat Mass	% Fat-free Mass	Waist Girth	Ulnar Deviation	Max Bench	Med Ball Toss	Grip Strength	Relative Strength
Bodyweight	-								
% Fat Mass	.38	-							
% Fat-free Mass	-.38	-1.0**	-						
Waist Girth	.66**	.08	-.08	-					
Ulnar Deviation	-.08	-.32	.32	-.14	-				
Max Bench	.70**	-.04	.04	.53*	-.02	-			
Med Ball Toss	.79**	.06	-.06	.59**	.06	.82**	-		
Grip Strength	.59**	.07	-.07	.47*	-.43	.71**	.66**	-	
Relative Strength	.29	-.25	.25	.27	-.21	.88*	.54*	.61**	-

*Significant at *P*<.05; **Significant at *P*<.01.

Table 4.17 Summary of stepwise regression analyses for prediction of planned agility from medicine ball toss and 20-m speed (n=19).

	Williams Agility Test					Illinois Agility Test				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
20-m speed	2.40	.333	.869	7.228**	.75	3.08	.256	.946	12.00**	.89
Step 2										
20-m speed						4.03	.368	1.238	10.94**	
Medicine ball toss						.015	.005	.355	3.131**	.94

Predictor variables entered: percentage of fat mass, medicine ball toss, relative strength, 5-m speed, and 20-m speed; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; Williams: F(1,17)= 52.24, *p*<.001; Illinois: F(2,16)= 114.19, *p*<.001; *Significant at *P*<.01; **Significant at *P*<.05.

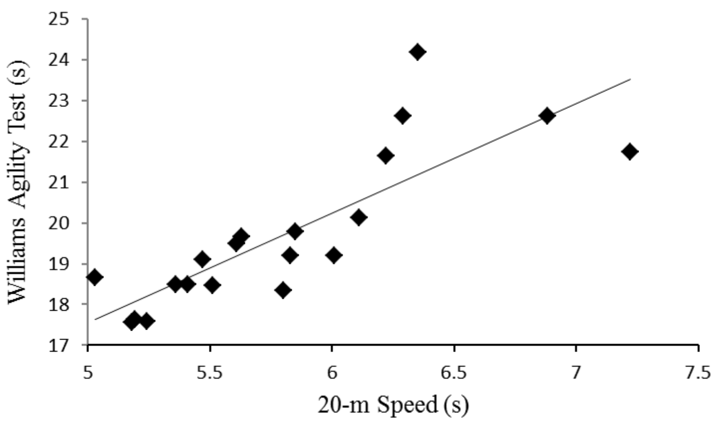


Figure 4.4 Relationship between 20-m Speed (s) and Williams Agility Test (s); y=5.6+2.5(x); R^2=.75; SEE=.81; n=19.

Ulnar deviation was the only significant predictor variable of reactive agility (see Table 4.10). When speed times were included in the regression analyses along with relative strength and ulnar deviation, 20-m speed was the strongest predictor for total test time (r^2=.41) (Table 4.18 and Figure 4.5).

Table 4.18 Summary of stepwise regression analysis for 20-m speed predicting reactive agility (n=20).

	Total Test Time				
	B	*SEB*	*β*	*t*	R^2
20-m speed	.442	.125	.640	3.538*	.41

Predictor variables entered: ulnar deviation and 20-m speed; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; Total Time: F(1,18)= 12.519, *p*= .002; *Significant at *P*<.01.

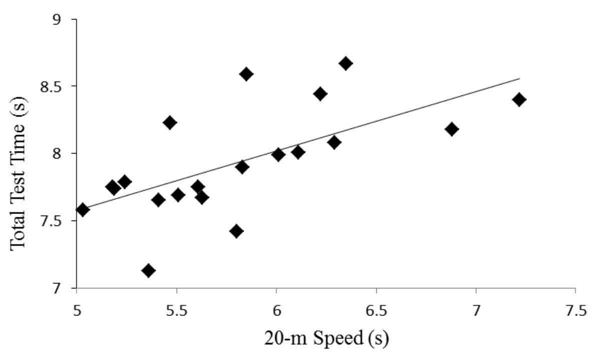


Figure 4.5 Relationship between 20-m Speed (s) and Reactive Agility Total Test Time (s); y=5.36+.44(x); R^2=.41; SEE=.31; n=20.

An overall best fit model was created for each speed test using the individual significant predictor variables (percentage of fat-free mass, bodyweight, waist girth, and medicine ball toss) and relative strength (maximum bench/bodyweight). Regression analysis indicated that the medicine ball toss and relative strength scores were the strongest independent predicators of 5-m sprint speed (Table 4.19). However, only the medicine ball toss entered into the regression equation for 20-m sprint speed (Table 4.19 and Figure 4.6).

Table 4.19 Summary of stepwise regression analyses for prediction of 5- and 20-m speed from medicine ball toss and relative strength (n=19).

	5-m					20-m				
	B	*SEB*	*β*	*t*	R^2	*B*	*SEB*	*β*	*t*	R^2
Med Ball Toss	- .007	.001	-.836	-6.277**	.70	- .011	.002	-.825	-6.027**	.68
Step 2										
Med Ball Toss	- .005	.001	-.633	-4.742**						
Relative Strength	-.464	.165	-.375	-2.804*	.80					

Predictor variables entered: percentage of fat-free mass, bodyweight, waist girth, medicine ball toss, and relative strength; *B*= regression coefficient (slope); *SEB* = standard error of regression coefficient; *β* = standardized regression coefficient; *t* = t-value; R^2 = coefficient of determination; 5-m: F(2,16)=31.588, *p*<.001; 20-m: F(1,17)=36.264, p<.001; *Significant at *P*<.05; **Significant at P<.01.

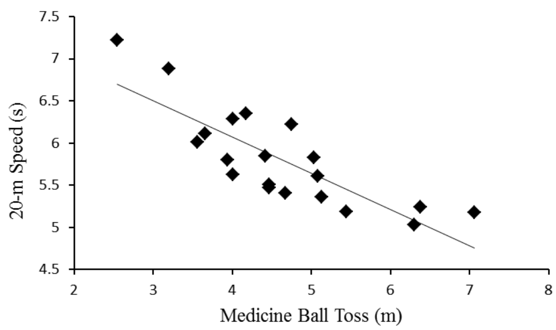


Figure 4.6 Relationship between 20-m Speed (s) and Medicine Ball Toss (m); y=5.06 + (-0.011x); R^2=.68; SEE=.21; n=19

Independent t-tests of significant univariate associations and competition designation, classification, and sex

Independent t-test analyses indicated that there was only one significant difference between competition level and all of the significant univariate predictor variables (percentage of fat and fat-free mass, bodyweight, ulnar deviation, medicine ball toss, 1-repetition maximum bench press, grip strength, and relative strength). The competitive group had a significantly stronger grip strength mean compared to the elite group (Competitive: 98.54 ± 20.55 kg, vs. Elite: 98.54 ± 20.55 kg, *p*=.004). There was also a significant difference between classification designation and bodyweight (Low: 59.95 ± 11.11 kg, vs. High: 70.24 ± 11.57 kg, *p*=.03) and the medicine ball toss (Figure 4.7). There were six significant differences between the sexes and the predictor variables listed above. Men were heavier, had larger waist girth, and stronger grip strength compared to the women (Bodyweight: Men: 70.85 ± 9.58 kg, vs. Women: 58.52 ± 11.49 kg, *p*=.01); (Waist girth: Men: 90.11 ± 10.73 cm, vs. Women: 68.81 ± 23.52 cm, *p*=.01); (Grip strength: Men: 108 ± 13.5 kg, vs. Women: 69 ± 23.5 kg, *p*=.000). Men also had higher scores in the medicine ball toss, 1-repetition maximum bench press, and relative strength scores (Figures 4.8, 4.9, & 4.10).

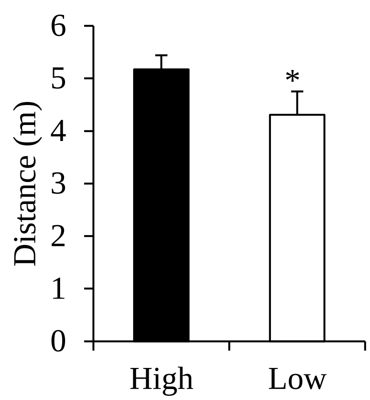


Figure 4.7 Mean ± SD medicine ball toss (m) in high and low classification groups. High = 5.17 ± 1.16 m, n=7; Low = 4.31 ± 0.98 m, n=13; *Significant at *P*<.05.

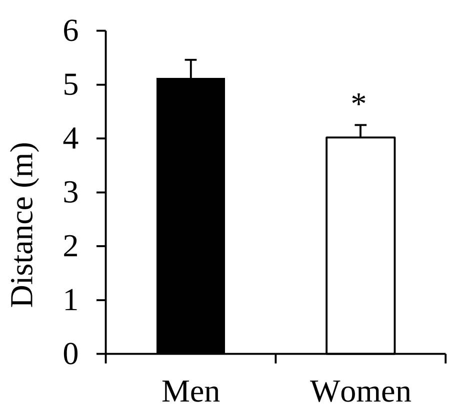


Figure 4.8 Mean ± SD medicine ball toss distance (m) for each sex. Men = 5.12 ± 1.03 m, n=9; Women = 4.02 ± 0.77 m, n=11; *Significant at *P*<.01.

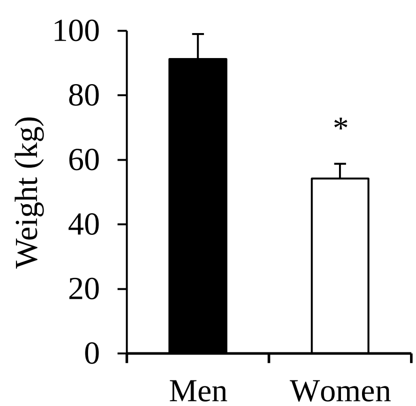


Figure 4.9 Mean ± SD maximum bench press (kg) for each sex. Men = 91.31 ± 21.73 kg, n=8; Women = 54.20 ± 15.33 kg, n=11; *Significant at *P*<.01.

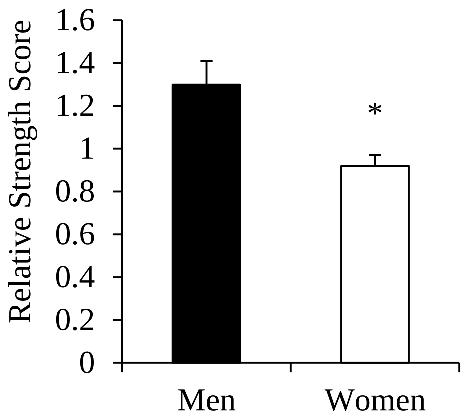


Figure 4.10 Mean ± SD Relative strength scores (maximum bench/bodyweight) for each sex. Men = 1.3 ± 0.31, n=8; Women = 0.92 ± .16, n=11; *Significant at $P<.01$.

Discussion

The primary finding of this study was that 20-m sprint speed and the medicine ball toss were the strongest predictors of planned agility. The other significant predictor of planned agility, percentage of fat mass, had high univariate associations but did not contribute to the overall model when a follow-up regression was performed using percentage of fat mass, medicine ball toss, relative strength, and speed as predictor variables. Twenty meter speed was also the strongest predictor for reactive agility performance. Table 4.17 provides some evidence that the Williams Wheelchair Agility test may be superior to the Illinois Agility test as the Williams test is more independent of speed (Williams: R^2=.75; Illinois: R^2=.89).

Our results indicate that the more powerful players were the fastest and more agile. We speculate that this may be a combined effect of the relationship between bodyweight and strength: larger players tend to be the strongest and a player's wheelchair may act as a "weight equalizer". The term "weight equalizer" stems from our assumption that once a high-end basketball wheelchair (with optimal wheelchair configuration) gets moving, there is little resistances and thus it is fairly easy to maintain top speed for a short duration. The fact that relative strength is only a significant predictor of 5-m speed and not 20-m speed provides some support for this theory.

There was a difference between classifications in regards to the medicine ball toss. We speculate that this may reflect the higher class's ability to engage more core muscles and greater trunk mobility when performing this test. This offers an advantage over the lower classification participants who cannot physically engage the same proportion of core muscle mass and who have less trunk mobility. Thus, although medicine ball toss appears to be a strong predictor of agility and speed, coaches and trainers need to be mindful of the potential impact classification has on testing results if using medicine ball toss as a sole measure of upper-body strength and power. The 1-repetition maximum bench press was not influenced by classification but it was highly correlated with the medicine ball toss ($r=.82$, $p=.000$). Therefore, combined measurements of upper-body strength and power may provide an accurate picture of a player's performance abilities regardless of classification.

Furthermore, when we used relative strength scores in our regression analyses, we found that participants' relative strength scores were moderately correlated with agility and speed (Table 4.15). Almost all the participants who had a relative strength score above 1.0 were ranked among the fastest and most agile. There were however some exceptions. Two participants had relative scores above 1 (1.05 and 1.01) but their speed and agility were slow. Poor chair set-up or poor pushing technique may have contributed to their slower speed and agility times (Mason, Porcellato, van der Woude, & Goosey-Tolfrey, 2010). The other exception involved 2 participants who had top 10 speed rankings despite weaker relative strength scores (below 1). One explanation may be that superior pushing technique could be compensating for lack of strength. Thus, increasing strength and relative strength (weight management) may be the most efficient way to impact speed for these 2 athletes.

In addition, we must also consider the possible impact sex may have on our results since power and relative weight appear to be significant factors for both speed and agility. In a previous study (Williams et al., unpublished data 2013) it was demonstrated that men were not more agile than women, despite being significantly faster in both the 5-m and 20-m straight-line sprint test trials. Thus, the impact of sex on agility for wheelchair basketball players remains unclear.

None of the wheelchair configuration measurements were found to be significant predictors of agility or speed, which is a surprise as previous studies have reported that seat height, camber, and wheel size impacted wheelchair maneuverability and speed (Mason et al., 2010; Mason, van der Woude, Lenton, & Goosey-Tolfrey, 2012; Wang et al., 2005). Our study design may be a reason why wheelchair configuration did not appear to be a significant predictor, as we tested participants in their regular basketball wheelchair versus testing them in various wheelchair set-ups. There were only small variations between wheelchair configuration measurements (Table 4.14).

It appears that agility is comprised of speed, strength/power, and competition level (assuming optimal wheelchair configuration). Theoretically, an athlete may be superior in one area (i.e. speed), which may compensate for a weakness in another area (i.e. wheelchair skills). However, in order for any athlete to reach his/her maximum potential, all 3 areas (speed, strength/power and wheelchair skills) ought to be trained specifically for wheelchair basketball agility.

Limitations and recommendations

The small sample size (n=20) was not ideal for regression analyses. In addition, there was no impact of wheelchair configuration on agility and speed detected. Another limitation of this study was that the use of air displacement plethysmography (i.e., BodPod) is a questionable measure for body composition in athletes with physical disabilities due to calculations that are based on assumptions about fat-free mass in able-bodied individuals (Reilly & Crossland, 2010). However, this method is believed to be reliable, thus data could be used to track changes in body composition for athletes with physical disabilities (Reilly & Crossland, 2010). This device is also easily accessible for all athletes and quick to use.

Conclusion

The main finding of this study was that speed (as indexed by 20-m sprint speed) and upper-body power (as indexed by the medicine ball toss) were the strongest predictors of planned of planned agility. Twenty meter sprint speed was the strongest predictors of reactive agility. The strongest predictors for the 5-m straight-line speed test were the medicine ball toss and relative strength. Combined these two variables accounted for 80% of the variance in 5-m sprint times. The medicine ball toss was also the only predictor variable entered into the stepwise regression model predicting 20-m sprint times (R^2=.68).

Due to the potentially significant impact upper-body strength and power have on wheelchair basketball performance, more studies focusing on strength training for wheelchair basketball players are warranted. In addition, specific agility training is also needed for wheelchair basketball players. As more valid measurements of body composition become feasible for disabled athletes, future studies should investigate the relationship between body composition, agility, and straight-line speed for wheelchair athletes. Lastly, additional studies on high performance wheelchair configuration should be performed as little research has been conducted in this area.

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