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Validity and reliability of field tests to assess performance of wheelchair rugby athletes: A preliminary study

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Abstract: Quality field tests of athletic performance are important tools for coaches and athletes to evaluate athlete capabilities and changes over time. Current field tests for wheelchair rugby have not been well evaluated. The purpose of this study was to examine the validity and reliability of five wheelchair rugby field tests (ball passing, two sprint tests, two agility tests). Wheelchair rugby players (n = 12) performed the field tests on 2 occasions, separated by 2 weeks, and performed a maximal isokinetic upper-extremity strength test (shoulder flexors and extensors). Spearman correlation was used to examine the relationship among the different field tests as well as to study the relationship with upper-extremity strength and athlete classification. Field test scores were evaluated for reliability across time with intraclass correlation (ICC) and the smallest detectable differences were determined. All tests, except passing, were highly correlated with each other ($\rho > 0.85$). Test-retest reliability (ICC) ranged between 0.89 – 0.99. Only the long sprint clockwise showed a good correlation with average upper-extremity force production ($\rho > 0.75$). All wheeling field tests had moderate to excellent correlation with athlete classification ($\rho = 0.75 - 0.90$). Based on these results, these wheelchair rugby field tests were deemed reliable and have discriminative validity (based on classification), though it may not be necessary to perform all tests to gauge an athlete's overall rugby skill level. Although the results are promising, a full validation should be conducted with a larger sample size.

Keywords: disability sport; quad rugby; physical disability; skills testing; athletic performance

Introduction

Wheelchair rugby is a competitive team sport designed for individuals with impairments in a minimum of three extremities such as cervical spinal cord injury (tetraplegia) or multiple amputations. For international competitions, players must meet minimum disability criteria and be classifiable under the sport classification rules as set by the International Wheelchair Rugby Federation. Developed by athletes with tetraplegia as an alternative to wheelchair basketball, wheelchair rugby is a fast-moving sport that involves actions such as passing, sprinting, and quick maneuvering of the chair.

Athletes who participate in competitive wheelchair rugby invest considerable time and effort to improve their performance. There are several studies that examined wheelchair rugby from different perspectives including, motion tracking and activity profiles (Rhodes et al., 2015; Sarro et al., 2010; Sporner et al., 2009), game efficiency (Molik et al., 2008;

Morgulec-Adamowicz et al., 2010), player classification, the effect of impairment on performance (Altmann et al., 2018; Altmann et al., 2017 Mason et al, 2019; Morgulec-Adamowicz et al., 2011), sprint kinematics (Haydon et al., 2018) speed profiles (Rhodes et al., 2018; Rhodes et al., 2017), monitoring of on-court training load (Paulson et al, 2015), training or competition intensity, and energy expenditure (Abel et al., 2008; Barfield et al., 2010; Borel et al., 2019). However, for rugby athletes and their coaches, it is also important to evaluate and understand the critical skill-related components of wheelchair rugby performance. Frequent and consistent measurement, using valid and reliable testing methods, can help to identify a player's weaknesses and strengths, and can monitor the effectiveness of training protocols. Field testing is one method of assessing a player's fitness and game-related skills. Field testing is also preferred over laboratory testing when assessing performance or physiological responses (Goosey-Tolfrey et al., 2021; West et al., 2016). Furthermore, field testing is typically more feasible for coaches and athletes as compared to laboratory testing because it involves significantly less time and does not require specialized equipment.

To date, little research has been completed on field-based testing in wheelchair sports (Goosey-Tolfrey & Leicht, 2013). In one of the few studies, field tests were developed and validated for wheelchair basketball (de Groot, Balvers et al., 2012). For wheelchair rugby, Yilla & Sherrill (1998) developed the first battery of field tests. A recent study examined a 20 m × 20 m repeated sprint field test and it was reported to be a reliable test, with physiological demands similar to that of wheelchair rugby (Gee et al., 2018). Orr & Malone (2010) reported a battery of five wheelchair rugby field tests, with statistically significant correlations with a player's wheelchair rugby classification (Malone et al., 2006). The test battery was adapted and refined by a national team coach for use during athlete assessments and team selection camps. However, further work is needed to determine the test-retest reliability of the wheelchair rugby field tests. In addition, to support validity of the fields tests, correlating the outcomes with a measure other than player classification, which is dependent on injury level and stable over time, is needed.

Researchers have shown that upper-extremity strength is highly predictive of wheelchair skill proficiency in patients with a spinal cord injury (Durán et al., 2001; Kilkens et al., 2005). Based on this evidence, upper-extremity strength may be a usable standard of validation for wheelchair rugby field tests given that upper-extremity strength represents components of a player's disability and their current training status. As such, we hypothesize that individuals with greater upper-extremity strength will perform better on the wheelchair rugby field tests.

Of interest for the conditioning and sport professional is whether it is necessary to perform all field tests or if there is overlap between tests regarding the skills they measure. Establishing the reliability and smallest detectable difference of each wheelchair rugby field test would provide the conditioning and sport professional with a standard by which to gauge significant changes in skill performance. In addition, given the importance of skills in wheelchair rugby, it is essential that the tests can distinguish different levels of players, e.g., by player classification (impairment) (i.e., discriminative validity) or muscle strength (related to impairment and training status) (i.e., construct validity). So, a battery of wheelchair rugby field tests that assess different components of the sport and is both valid and reliable is necessary for athletes and coaches at the introductory and elite levels in order to evaluate training status and effectiveness of training protocols (Malone et al., 2011).

Therefore, the purpose of this study was to assess correlations among performance-related components of wheelchair rugby, as well as examine the reliability and validity of five wheelchair rugby field tests (Orr & Malone, 2010) among a group of competitive wheelchair rugby players.

Materials and Methods

This study was designed to examine an existing battery of wheelchair rugby field tests (Orr & Malone, 2010) and make recommendations regarding their utility for athlete testing and assessment. Experienced and trained investigators carried out the experimental procedures. Wheelchair rugby athletes from two countries (USA, Netherlands) performed the test battery on two occasions, with two weeks separating the testing. To ensure that testing procedures were conducted the same at each location, a written script of the protocol was followed. Players were recruited from convenience samples of local players who had been participating regularly in wheelchair rugby for at least one year.

By analyzing performance on the test battery across two different days, test reliability and smallest detectable difference could be determined. Upper-extremity force production and player classification were utilized to validate the test battery.

The University Research Ethics and Institutional Review Boards at both institutions approved all tests and protocols, with signed informed consent given by all participants.

The field tests were performed in gymnasiums where the teams typically trained. It took approximately 30-45 minutes for each player to complete the test battery. Participants had a minimum of 2 minutes rest time between test items. The following wheelchair rugby field tests were completed in the following order. Schematic drawings are located in Appendix A.

Ball Passing (BP)

The passing test involved throwing or bumping (hitting the ball with a fist or forearm) a wheelchair rugby ball from six different positions to a standardized target. The target consisted of an inner square (15 cm x 15 cm), surrounded by a rectangle (60 cm wide x 45 cm high), with an outer square (105 cm x 105 cm) rotated at 45 degrees to create a diamond shape around the inner portions. Low point players (0.5–1.5) threw or bumped the ball from three locations (left, center and right) at a distance of 10 and 15 ft (3.05 and 4.57 m) from the target. High point players (classes 2.0–3.5) threw or bumped the ball at the target from left, center and right from a distance of 15 and 20 ft (4.57 and 6.10 m). The right and left passing locations were 6 ft (1.83 m) from the center location. For the right and left passes, participants threw the ball with the respective hand. Participants made 5 passes from each spot and a score for each pass was assigned according to the location on the target that they hit. Hitting in the center square scored 3 points, middle rectangle scored 2 points, and outer diamond scored one point. When the ball hit a line, it scored for the higher point value (inside score). Missing the target or misfiring the ball scored 0 points. The sum of all scores was the total passing score.

20-Metre Straight Sprint (SS)

Participants began in a stationary position, with the front casters behind the start line and pointing in the driving direction. The participant indicated to the tester when they were ready to begin; the tester began timing as soon as movement was initiated. Participants sprinted forward 20 m from the start position in a straight line. The time ended when the participant's front casters crossed the 20 m line. Each participant performed three trials. The final score was the average of these three trials.

Long Sprint (LS)

Participants began in a stationary position at the half-court line, with the front casters behind the line and pointing in the driving direction. Participants sprinted to a cone at the baseline, round the cone, sprinted to the opposite baseline cone, rounded the cone and finished at the same place they began. As in the 20 m sprint test, the tester began timing as soon as movement was initiated. The time ended when the participant's front casters crossed the center court line. Total distance travelled was 56 m. Three trials were attempted for each participant in clockwise (LSCW) and counterclockwise (LSCC) direction. An average score was calculated for each direction.

Up and Back (UB)

Participants began in a stationary position at the baseline, with the front casters behind the line and pointing in the driving direction. Participants sprinted in a forward direction to each of 7 lines measuring 36 in. (91.44 cm) apart with the first line being 40 in. (101.6 cm) from the baseline. Participants passed the front casters over each line and then reversed directions (wheeled backwards) back to the baseline each time. Time began upon initiation of movement by the participant, and stopped when the participant passed the baseline, with the rear wheels, from the final line. Each participant completed one trial. The score was the time needed to complete the entire up and back test.

Slalom

Participants began in a stationary position at the baseline on one side of a cone, with the front casters, pointing in the driving direction, behind the baseline. The participant weaved through 7 cones, each 48 in. (121.92 cm) apart, to the end, round the final cone and returned to the baseline. Timing began upon initiation of movement by the participant and ended when the front casters crossed the baseline. Participants performed this pattern without a ball (SL), and with a ball (SLB) that was dribbled every 10 s. Participants performed two trials in each condition (with and without the ball) beginning one trial from the right side of the cone and the other from the left side of the cone. If a participant hits a cone during the trial, one second was added to the total time for each cone contacted. If a ball dribbling violation occurred, 5 s were added to the time. There are two end scores: average time for the slalom with ball and the average time for the slalom without the ball.

Upper-extremity force production

Upper-extremity force production was tested once for each participant using the Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA). This was done on a separate day after completion of the wheelchair field tests. The dynamometer measured the maximal force during concentric closed-chain shoulder flexion and elbow extension (push) and shoulder extension and elbow flexion (pull) motions. This closed-chain motion was chosen because it is a dynamic task (de Groot, Dallmeijer et al., 2012) that resembles wheelchair propulsion. Participants were secured in the testing device using adjustable straps around the waist and across the chest. Hand straps were used for most participants to improve their ability to grip the dynamometer handle. Participants started the test with the hand positioned underneath the shoulder and the elbow at 110 degrees. Participants were instructed to push and pull against the dynamometer handle as hard and as fast as possible for three repetitions. A relatively slow velocity of 23 cm/s was chosen to elicit maximum torque without loss of coordination. Each participant completed two sets of three repetitions with each arm (six repetitions in total per arm). The average of the six repetitions of the push and pull measurements were recorded as Average Force.

Statistical analyses

SPSS version 20 was used for all statistical analyses. A Spearman correlation was performed among the wheelchair rugby field test scores to determine the association between different components of wheelchair rugby skills.

Reliability was assessed according to the Generalizability Theory, which is based on analysis of variance (ANOVA). Variances were obtained from variance component analyses with a random design and the method of restricted maximum likelihood. Three components of variance were estimated with the analysis, i.e. variance attributable to the individual (var_{id}), trial (var_{trial}) and residual error (var_e). The intraclass correlation coefficient (ICC), the standard error of measurement (SEM), and the smallest detectable difference (SDD) were calculated with these variance components for all the wheelchair rugby field test scores. The following interpretation was used for the ICC: 0.00–0.25, little to no correlation; 0.26–0.49, low correlation; 0.50–0.69, moderate correlation; 0.70–0.89, high correlation; and 0.90–1.00, very high correlation (Munro, 2004).

Discriminative validity was evaluated by investigating whether higher classification players scored better on the wheelchair rugby field tests than those with lower classification. Construct validity was evaluated by investigating whether players who produced greater average upper-extremity push and pull force performed better on the field tests than those who produced lower maximum force. These validity analyses were examined using Spearman correlations. Validity was considered good when the correlation coefficient between the item score and classification, and the item score and upper-extremity force production were greater than 0.75. Due to slight differences in measurement protocol between the two test sites, validity for the Up and Back test and correlations with the other wheelchair rugby field tests was not calculated.

Results

Participants

Twelve wheelchair rugby athletes (n=6, USA, competing at a national or international level; n=6, Netherlands, all competing at a national level) were a convenience sample and consisted of 11 males and had a mean age of 36.2 (7.3) years. The disability of the athletes included tetraplegia (N=9), amputation (N=1), cerebral palsy (N=1) and arthrogryposis (N=1), while their classifications were 0.5 (N=2), 1.0 (N=3), 2.0 (N=3), 2.5 (N=2), and 3.0 (N=2).

Correlation among field tests

The correlation matrix between all test items is shown in Table 2. The skills tests based on time as a measure of performance showed high correlations (>0.85) with other 'speed' items, but that the passing task showed weaker correlation with the timed tasks (ρ = -0.44 to 0.69).

Table 2. Spearman correlations between wheelchair rugby field tests.

	BP	SS avg	LSCW avg	LSCC avg	SL avg
SS avg	-.44	-	-	-	-
LSCW avg	-.69	.88	-	-	-
LSCC avg	-.65	.90	.98	-	-
SL avg	-.57	.87	.89	.91	-
SLB avg	-.66	.85	.86	.86	.97

Note: Correlation is significant at the 0.05 level (2-tailed, indicated by **light gray cells)** or 0.01 level (2-tailed, indicated by **dark grey cells).** BP = **b**all **p**assing, SS = **s**traight **s**print, LSCW = **l**ong **s**print **c**lock**w**ise, LSCC = **l**ong **s**print **c**ounter **c**lockwise, SL = **s**lalom without ball, SLB = **s**lalom with ball, avg = average time. Analyses were not conducted for the up and back.

Reliability

The test-retest reliability results are shown in Table 3. All of the test items were high to very high reliability, when performed on one day (trial 1) (ICC >0.89) and were only slightly better when the tests were performed on two days (trial 1 and 2) and when the average was taken over these days (ICC >0.9; Table 3). The SDD varied between 9-38%. The SDD was especially high for the ball passing test (13.6 points) thus, this test may not be useful for tracking change over time, since a player must improve by nearly 14 points to have an improvement beyond the measurement error. When performing the test twice and taking the average, the SDD was smaller (9.6 points improvement).

Table 3. Reliability and smallest detectable differences (SDD).

	Mean1 (SD)	Mean2 (SD)	ICC1	ICC2	SDD 1 trial	% SDD 1 trial	SDD 2 trials	% SDD 2 trials
Ball Passing	34.2 (17.3)	36.7 (15.0)	0.91	0.95	13.6	38.4	9.6	27.2
Straight Sprint - avg	7.9 (1.6)	8.0 (1.6)	0.96	0.98	0.88	11.03	0.62	7.80
Long Sprint CW - avg	28.6 (8.7)	29.2 (9.2)	0.99	0.99	2.6	9.0	1.8	6.4
Long Sprint CC - avg	28.5 (7.9)	28.5 (8.8)	0.98	0.99	3.0	10.6	2.1	7.5
Up and Backs*	70.4 (22.6)	72.3 (20.0)	0.89	0.94	19.3	27.0	13.6	19.1
Slalom without ball - avg	17.2 (3.6)	17.5 (3.8)	0.96	0.98	1.98	11.4	1.4	8.1
Slalom with ball - avg	20.6 (6.5)	19.9 (5.7)	0.93	0.96	4.5	22.0	3.2	15.6

Note: CW = clockwise, CC = counter clockwise, avg = average time, SD = standard deviation, ICC = intraclass correlation, **SDD = smallest** detectable difference, %**SDD** = percent change in mean score needed to detect a significant improvement. *Only performed once per trial.

Validity

The correlation between the scores on individual test items, upper-extremity push and pull force production and wheelchair rugby athlete classification are shown in Table 4. The correlation coefficients between the wheelchair rugby classification and the test items were higher than the correlation between upper-extremity force production and the seven test items in Table 3. All tests, except for the ball passing test, had good correlations with athlete classification (r = .75 - .90). Only the long sprint clockwise had a good correlation with upper-extremity force production (r = .77) whereas ball passing had the lowest correlation (r = .36 - .45).

Table 4. Spearman correlations between field tests and strength measures, and between field tests and athlete class.

	Avg Push Force	Avg Pull Force	Athlete Class
Ball Passing	.36	.45	.55
Straight Sprint avg	-.60	-.69	-.85
Long Sprint CW avg	-.64	-.77	-.90
Long Sprint CC avg	-.49	-.73	-.83
Slalom without ball avg	-.46	-.55	-.75
Slalom with ball avg	-.51	-.52	-.75

Note: Correlation is significant at the 0.05 level (2-tailed, indicated by light gray cells) or 0.01 level (2-tailed, indicated by dark gray cells). CW = clockwise. CC = counter clockwise. avg = average time. Analyses were not conducted for the up and back.

Discussion

Quality field tests of athletic performance are important tools for coaches to evaluate athlete capabilities and changes over time. In the current preliminary study, it was shown that the five wheelchair rugby field tests had a high correlation with each other, most of the tests had an excellent test-retest reliability, the discriminative validity was good for most tests while the construct validity was only good for the long sprint clockwise.

Our sample included a distribution of age, gender, disability, and player classification as seen among wheelchair teams. The heterogeneity of the sample, however, may have led to higher ICC values (de Vet et al., 2001). When assessing reliability, a high to very high ICC was found for all tests except passing. Some of the tests had a high SDD, when performing the test once, indicating that it may be difficult to detect change over time when such a large improvement is necessary to exceed the measurement error. A high correlation was found among the five field tests, indicating that it may not be necessary to perform the entire test battery to assess the range of skills. If some tests were deleted from the battery, it might be good to perform the selected tests two to three times in one testing session to improve the SDD, which would allow for smaller differences to be meaningful when detected over time. For example, one of the two sprint tests (long or 20 m) and the slalom with the ball could be performed twice each in one testing session and would give coaches and athletes an accurate assessment of sprinting, agility, and ball handling skills, without needing to perform a second set of sprint tests and slalom without the ball.

Ball passing had the highest SDD, similar to the results of De Groot, Balvers and colleagues (2012), who studied passing and shooting tests in wheelchair basketball players. In the current study, the high SDD score suggests that a large change would be needed to detect a difference. Shooting and passing skills are more likely related to player experience and are therefore beneficial to measure improvement across time. The SDD decreases when the test is performed more than once in a testing session, indicating that it may be beneficial to perform the test more than once for each player. Player class and role on the court should be taken into consideration during test interpretation by coaches because some players' roles are focused on blocking maneuvers and they do not frequently handle the ball in a game (Malone et al., 2006; Molik et al., 2008; Morgulec-Adamowicz et al., 2010).

Most wheelchair rugby teams, in particular high-level competition teams, have limited group practice time, which limits the amount of time that a coach can allot for assessment. The current test battery from start to finish took 30 to 45 minutes. Although this is not a lot of time per player, by the time the entire team runs through the battery, valuable training time is lost (3+ hours, up to a full day, depending on the size of the team), which may be more time than coaches are willing or able to allot to testing. Therefore, the next step in this research is to determine the minimum set of field tests needed to measure the important components of skilled wheelchair rugby player performance.

Overall our results showed that the battery of tests, except for passing, correlated well with player classification, which is consistent with previous studies (Malone et al., 2006). Players with greater functional ability scored higher on the field tests. In this current study, we demonstrated that upper-extremity strength had a strong correlation with the long sprint clockwise, whereas passing showed the lowest correlation with push and pull force. Our results indicated that players with higher classifications generally performed better on most test items, and some performance aspects might improve with increased upper-extremity strength. Although strength might be related to impairment, it is also associated with training status and, therefore, it can be improved by changing a player's training regimen. We found that the passing test had the lowest correlation with both player classification and strength, indicating that this may be a skill related to playing experience, which was not examined in this study. Although the SDD was large, passing is nevertheless a valuable skill worth evaluating since it is an important skill during a wheelchair rugby match. Similar results were found for wheelchair basketball, i.e., the shooting and passing items were the least reliable and valid test items and, although important skill items, they should be interpreted carefully (De Groot, Balvers et al., 2012). Perhaps a consideration for future reliability and validity studies would be to test only the dominant arm.

A limitation of this study is the small sample size. Similar comparatively small sample sizes are often seen in reliability studies in the area of rehabilitation or adapted sports, especially those that include persons with a severe disability (Cowan et al., 2012; Holland et al., 1994; Leicht et al., 2013). In addition, the majority of participants had tetraplegia, whereas the ...sport of wheelchair rugby includes a wider range of disabilities including limb deficiency, cerebral palsy, polio and others. One factor that may have affected the passing test results, but was not measured, is specific impairment of the arms and trunk. Studies have shown that arm and trunk impairment have varying impacts on the performance of activities (Altmann et al., 2018; Mason et al., 2019). Most likely, the athletes with multiple amputations, arthrogryposis and cerebral palsy had some trunk function and a lower arm score than athletes with the same overall classification with spinal cord injury. Yet, the ball passing tests, may, in large, be determined by arm impairment. However, the ball passing tests were stratified based on overall classification, i.e., different passing distance for low and high point players, in contrast to the other field tests. In addition, information regarding players' training hours, years of experience, and severity of impairments was not available. Furthermore, timing gates would have been more accurate than using a stopwatch. However, not every wheelchair rugby team will have timing gates because they are much more expensive than a stopwatch and, therefore, the reliability of the stopwatch measurements were assessed. Lastly, there is no gold standard regarding wheelchair skill performance and, therefore, making validity testing difficult. Researchers who plan to do future studies in this area are advised to include a subjective assessment of the coaching staff of the wheelchair skill performance of the players to compare the objective results with. Data were collected at two sites and efforts were made to ensure that testing measures were identical between sites, however, minor differences in testing procedures for the Up and Back test were identified in the analysis phase, therefore, this test could not be utilized in all analyses limiting our ability to assess validity for that particular test.

Conclusions

Overall, based on the small sample size, the results of this study might indicate that these wheelchair rugby field tests are reliable, have discriminative validity (based on classification), and are a useful tool for assessing athlete performance, as both individual tests and as a testing battery. Although the results are promising, fully powered validation should be conducted with a larger sample size.

Perspectives

Interpretation of the study results lead to recommendations of how the field tests can be used by the conditioning specialist or wheelchair rugby coach. All tests, except passing, were highly correlated with each other indicating that fewer tests could be included in the battery. The long sprints need not be conducted in both the clockwise and counterclockwise directions and slalom tests not with and without the ball, so time could be saved eliminating one of these tests. The 20 m and long sprinting were also highly correlated, so only one of those tests may be needed.

The wheelchair rugby tests were found to be reliable but some tests had a high SDD. It is therefore recommended to perform some tests twice, and use the average score, to diminish the SDD and to be able to evaluate the skill performance of a player at specific time points during the season. Passing of the ball is critical in wheelchair rugby, but the low reliability and validity should be taken in account when interpreting the test results. The tests may provide useful information for team selection and training.

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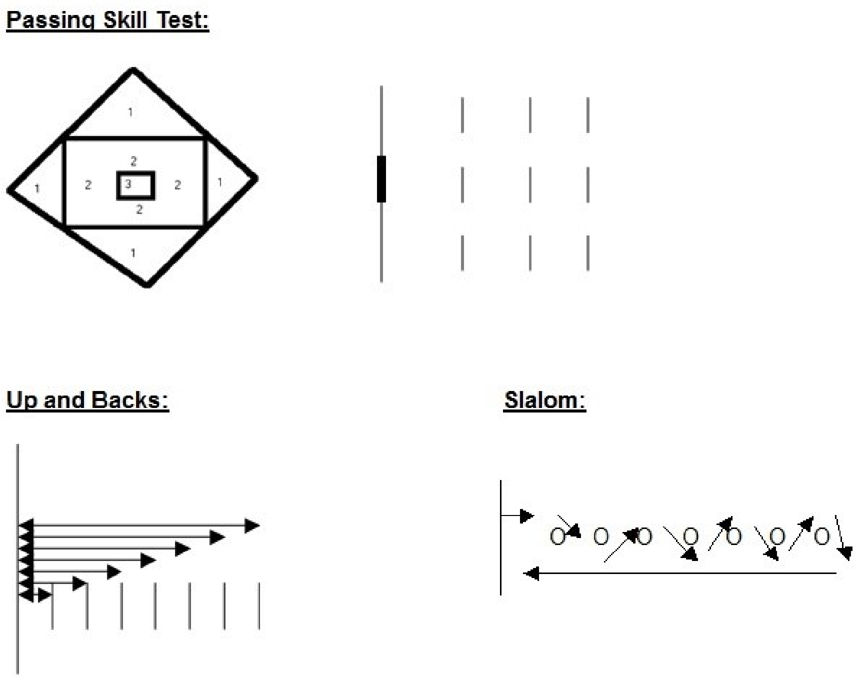
Appendix A



Schematic drawings of the following wheelchair rugby field tests: Passing skill, Up and Backs, Slalom. Additional details (e.g., execution, dimensions) for each test are described in the methods section and elsewhere (Orr & Malone, 2010).

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