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Factors Influencing Speed of Collegiate Wheelchair Basketball Players

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ABSTRACT

Introduction

Sprinting determines a player's potential to initiate the next action. Previous studies have focused on wheelchair configuration and propulsion biomechanics for optimal performance in wheelchair sports.

Purpose

The purpose of this study was to determine influential factor(s) affecting the speed of collegiate wheelchair basketball players.

Methods

Eleven women (W: 22.3±4.8 yrs) and 13 men (M: 24.3±5.9 yrs) of University of Texas at Arlington's (UTA's) Wheelchair Basketball teams participated in this study. Participants were grouped based on gender and player classification (1.0-2.5 and 3.0-4.5). Dual-energy X-ray absorptiometry (DXA) scans assessed body fat percentage (BFP). Bilateral handgrip (kg) and 1-repetition maximum bench press tested muscle strength (lb). The first 15 ft of a 20 m sprint were video-recorded and analyzed to obtain values of trunk and elbow flexion (°) and contact and recovery time (sec).

Results

Lower classified (1.0-2.5) men and women had correlations between initial trunk and elbow flexion (M: r=0.73; W: r=0.84) and 15 ft time and initial elbow flexion (M: r=0.75; W: r=0.71). Low classified (1.0-2.5) men had negative correlations in the handgrips and both 15 ft and 20 m times (R hand 15 ft time: r=-0.89; R hand 20 m time: r=-0.75; L hand 15 ft time: r=-0.81; L hand 20 m time: r=-0.93). Body fat percentage influenced both 15 ft and 20 m times for high classified (3.0-4.5) men (15 ft: r=-0.74; 20 m=-0.78) and the 15 ft times for lower classified (1.0-2.5) women (r=0.88).

Conclusion

Initial elbow flexion and handgrip were important for lower classified (1.0-2.5) men. Low classified (1.0-2.5) women had faster 15 ft times with larger degrees of elbow flexion. Body fat percentage affected higher classified (3.0-4.5) male players. Additional factors may be identified in future research.

Keywords

Disabled sports; Biomechanics; Paralympic sport; Strength exercise.

INTRODUCTION

Research in the field of adaptive sport has been growing. Physical activity has tremendous benefits for an individual's health, physical functioning, and social relationships. Recently, competitive sport for people with disabilities has grown rapidly. Exercise develops social integration for people with disabilities by improving their self-confidence, self-competency and life quality.[1-3] In recent studies, the focus of adaptive sport has begun to focus on wheelchair propulsion biomechanics and optimal wheelchair configuration for the adaptive athlete to be most successful in his or her respective sport. The two major components of wheelchair sport performance are the athlete and the wheelchair.[3-5] Wheelchair sport biomechanics research focuses on the relationship between the user and the wheelchair, as well as their ability to generate force using their upper body. Wheelchair set up and configuration plays an important role in this relationship. Previous research has shown that there is a trade-off between wheelchair configuration and capacity to generate force.[6] The overall standards for the design of a wheelchair sports chair remains consistent for any wheelchair sport: the fit; minimizing weight while maintaining high stiffness; minimizing rolling resistance; and optimizing the sport-specific design of the chair.[7-9]

Wheelchair basketball is the most popular sport for athletes with disabilities.[10] According to the International Wheelchair Basketball Federation (IWBF), a player's level of trunk function directly affects the performance of different skills.[10] Individuals with a variety of disabilities can participate in wheelchair basketball. Spinal cord injury, cerebral palsy, musculoskeletal conditions, spina bifida, amputation and poliomyelitis are all lower-limb conditions that reduce an individual's ability to play running basketball similar to able-bodied players. Using sport-specific manual propulsion wheelchairs, performance depends on endurance, strength, speed, coordination and mobility.[11] In an attempt to provide parity and opportunity for individuals of all levels of function to play, players are grouped into categories or classes ranging from 1.0 (least physical function) to 4.5 (most physical function), and only a certain number of points are allowed on the floor at any given time. Classification is based on the function of the trunk, the upper extremities, the lower extremities and the hands, relying mostly on the movement and stability of the player's trunk.[1,5,9] Trunk movement and stability is based on the athlete's physical capacity to perform fundamental basketball movements such as pushing their chair, dribbling, shooting, passing, catching, rebounding, and reacting to contact.[9,12]

Similar to able-bodied athletes, wheelchair athletes look for more efficient ways to train and improve their technique or fitness.[5] For example, the ability to perform a sprint as fast as possible is important for wheelchair basketball players as speed determines the player's opportunity to take initiative of the next action.[13] Wheelchair basketball requires the players to perform numerous short periods of high or maximum intensity exercise and sprint actions.[10] More specifically, maneuverability and high accelerations from standstill or coasting is important for the player's ability to respond to and anticipate movements.[14] The most helpful studies have resulted from data gathered in circumstances that are close to the specific sport setting, with athletes in their own wheelchairs and in a field-based test.[13] Field-based tests create similar environments to the actions and movements of training and games.[12] Existing research studies concerning wheelchair basketball performance have included sprint tests, strength testing, analyses of hand rim wheelchair propulsion and body position in the chair, and comparison of player classifications.[1,4,9,10,13,14] The purposes of these studies have focused on wheelchair propulsion biomechanics, push characteristics in wheelchair court sprinting, and wheelchair configuration for optimal mobility performance in wheelchair sports.[1,6,10,11] This study focuses on the biomechanics of the wheelchair basketball player's manual propulsion and factors directly related to the participant rather than external factors or wheelchair configuration. Methods and procedures utilized in this study are similar to those of previous research in order to observe different features of the tests and the implications of any major findings. The purpose of this research study was to determine the most influential factor or factors that affect the speed of collegiate wheelchair basketball players by analyzing video-recorded 15 ft sprints and player information.

METHODS

Participants

All twenty-four (24) participants were current students between the ages of 18 and 45 years at the University of Texas at Arlington (UTA) on the roster for the men's or women's Movin' Mavs Wheelchair Basketball teams. All participants were not injured or recovering from an injury by the time of the first meeting with the primary investigator. Participants were excluded if they were pregnant, injured or recovering from an injury, if they were not students enrolled at the UTA, or if they were not wheelchair basketball players that compete at the collegiate level. Subjects were grouped based on gender and separated into two groups based on player classification (1.0-2.5 or 3.0-4.5). Correlations were calculated to determine any relationships between player information and video analysis variables with the times of the 15 ft and 20 m sprint times.[15] Subjects were grouped due to a smaller sample size, and previous research has used similar groupings to stratify players.[11,16] From a functional capacity stand point, the primary difference between a 2.5 and a 3.0 is control of trunk flexion and trunk extension. Class 3.0 players and above demonstrate complete control during trunk flexion/extension, whereas class 2.5 players and below demonstrate an inability to control the trunk during trunk flexion and are unable to return to an upright position *via* trunk extension.[5,9,17] In this study, participants were classified according to the Player Classification Manual of the IWBF: Class 1 (men: n=4; women: n=2), Class 1.5 (men: n=2; women: n=1), Class 2 (men: n=1; women: n=2), Class 2.5 (men: n=1; women: n=0), Class 3 (men: n=0; women: n=3), Class 3.5 (men: n=1; women: n=2), Class 4 (men: n=2; women: n=0), Class 4.5 (men: n=2; women: n=1). Disabilities in the lower classification (1.0-2.5) group included spinal cord injuries and spina bifida. Higher classification (3.0-4.5) disabilities included lower limb amputations and lower limb deficiencies.

Participants met with the primary investigator on three separate occasions. During the first meeting, the primary investigator reviewed the informed consent document with the subject, answered any questions or concerns from the subject, and the subject signed the form once comfortable with participating in the study. Participants were assigned a subject number upon signing the consent form. Participants also completed strength tests and provided basic player information during the first meeting. Basic player information consisted of age, mass, height, player classification, the size of the wheels on the subject's sports chair, and measuring the subject's wingspan. Age and height were self-reported. Mass was measured (Health O Meter Pro Plus weighing scale) with participants in their wheelchairs then the wheelchairs were weighed empty and that weight subtracted from the weight of the athlete plus the wheelchair. The size of the wheels on the sports chair were standard sizes and varied between 24 and 27 inches in diameter. Wingspan (m) was measured using a measuring tape.

Strength Testing

During the first meeting, participants completed a bilateral handgrip strength test similar to the procedure in the study conducted by Rodgers et al in order to provide an objective index of general upper body strength.[6] All participants used the same handgrip dynamometer (Jamar Technologies, Hydraulic Hand Dynamometer, Sammons Preston, Inc. Bolingbrook, IL, USA). Hand dominance was determined before starting any trials. All trials were completed with the participant seated in their day chairs, shoulder adducted and neutrally rotated, elbow by the side and flexed to a 90° angle, and forearm and wrist in neutral position. Participants alternated hands until completing three trials of each hand, resting 10-20 seconds between each trial to avoid the effects of muscle fatigue. During the rest period, the primary investigator recorded the results of the trial on the data collection sheet and reset the hand dynamometer back to zero.

Participants completed a one-repetition maximum (1 RM) bench press strength test similar to the procedure in the study conducted by Niewiadomski et al to measure the participant's ability to maximally lift weight through the full range of motion of a flat barbell bench press.[18] Depending on the participants' level of disability, the one-repetition maximum bench press was completed on a standard bench (3.0-4.5) or on the Olympic or the chest press BodyMax machine (1.0-2.5). All participants performed three total warm up sets. The first set consisted of five to ten submaximal repetitions with a weight equal to 40% of the participant's body weight. The following two warm up sets were between 50-60% of the participant's body weight and two to five repetitions. There were two minutes of rest between warm up sets. After warming up, the sets were single repetition as the weight approaches the participant's maximum. The 1-repetition maximum final weight lifted was achieved within four attempts. Exceeding four attempts risked compromising the participant's strength due to the volume of work already done. The weight for each set was recorded on the data collection sheet. The final 1 RM bench press value was used for data analysis.

Body Composition

The players on the men's and women's wheelchair basketball teams at UTA completed DXA scans. The scans provided the player's height (in) and mass (lb) and were validated by the player during the first meeting with the primary investigator. Body fat percentages from the scans were used for data analysis. DXA scans had to be completed before the player was allowed to begin any testing.

Speed Testing

Procedures for the second and third visit reflect those used by Yanci et al and consisted of the participant's completion of two separate video-recorded sprints.10 Participants performed a maximum effort sprint for 20 m. The first 15 ft was video-recorded using a (GoPro Hero 6) camera set on "Video" at a resolution of 1080 at 60 fps and placed on a tripod in the middle of the 15-foot sprint near the edge of the key closest to the participant. The Motion Sensor and first PhotoGate pair, as well as the player in starting position, were kept in the frame. Participants started on the baseline of one side of the basketball court. Once the principal investigator (PI) had the recording system ready, participants were instructed to perform a maximum effort push, sprinting towards the baseline on the other end of the court. Participants began when they were ready from a stationary start. Sprint time began when the players passed through the first PhotoGate pair. The fastest video-recorded sprint time was used for data analysis.

The timing system used for data collection was a Brower Timing System with two PhotoGate pairs and TC-Motion Start using start on detection. Passing the PhotoGates initiated the start and finish of the 20 m sprint. One PhotoGate pair was placed at the 15-foot mark (4.57m) of the 20 m sprint to record the time for the 15-foot sprint. The other PhotoGate pair was placed at the 20 m mark for the end of the sprint. For the purposes of this study, the first PhotoGate pair was programed to the first beep (maximum of 10 m), and the other pair programmed to two beeps (maximum of 22 m). The TC-Motion Start sensor was placed at the starting baseline. The TC-Motion Start sensor beeped when the motion of the participant's movement was detected. The times for the 15-foot time, the split time, and the total 20 m sprint times were displayed on the screen of the TC-Timer. The TC-Timer was set to "Chronograph Mode" to show the display number, the 15-foot time, the split time, and the 20 m sprint time.

Kinovea Video Analysis

The participant's fastest video-recorded sprint time was used for video analysis. Data collected from the video recording included the total 20 m sprint time, 15-foot sprint time, number of pushes for the 15-foot sprint, number of pushes for the 20 m sprint, contact angle and recovery time of hands on the wheel, and trunk and elbow flexion. Video data was analyzed using Kinovea Motion Analysis software on a computer. Kinovea is a free software application used for 2D motion analysis and can measure passive and active range of motion, position, velocity, and acceleration. This data can be exported to a spreadsheet for further analysis. This software has been used in previous research examining the biomechanics of wheelchair sports and has been shown to be reliable compared to other 2D motion analysis software.[19-21]

A participant's fastest video recorded sprint was opened in the Kinovea software. Videos were played back at a speed of 15% to allow the primary investigator to observe hand contact and release on the wheel of the participant's sports chair. The contact and recovery times (sec) were measured using the time posted as "position" of the frame in the video. Contact times consisted of the entire duration at which the participant's hand contacted with the wheel of their sports chair. Recovery time was the amount of time the hand spent off the wheel before making contact again. Initial contact and recovery times (sec) were recorded and subsequent values for each were averaged.

Trunk and elbow flexion were also analyzed using Kinovea. Videos were played back at a speed of 15% to measure the degree of trunk and elbow flexions (°) at the same frame as the participant's first hand contact with the wheel of their sport's chair after recovery time. Using the angle tool, the primary investigator measured the degree of trunk flexion (°) by placing the vertex of the angle on the greater trochanter of the participant, one ray following the femur, and the second ray following the spine. Elbow flexion was measured by placing the vertex on the trochlea of the participant's elbow with one ray following the radius and ulna, and the second ray following the humerus. Internal angle measurements were used for both trunk and elbow flexion values.

Statistical Analysis

Data values from strength testing, DXA scans, and player information were recorded on an Excel spreadsheet. Correlations were calculated for men and women of both classification groups using Excel's "CORREL" function. Correlations with a strength of r=0.70 or higher were identified as influential to the speed of the wheelchair basketball players' sprints.[22]

RESULTS

Participant Data

Participants were grouped based by gender and separated into two groups based on player classification (1.0-2.5 or 3.0-4.5). According to Table 1, men (n=13) had a mean age of 21.63±2.83 years for the lower classification group (1.0-2.5) and 25.75±4.03 years for the higher classification group (3.0-4.5). Men in the 1.0-2.5 classification group had a mean mass of 74.49±25.07 kg and a mean height of 1.69±0.33 m. High classified (3.0-4.5) men had a mean mass of 82.82±6.62 kg and a mean height of 1.76±0.11 m. Wingspans were calculated as 1.74±0.24 m for the lower class (1.0-2.5) and 1.81±0.09 m for the higher class (3.0-4.5). Mean body fat percentages for the men were 26.65±12.48 percent for the 1.0-2.5 class and 26.99±5.01 percent for the 3.0-4.5 class.

Women (n=11) had a mean age of 23.00±7.35 years for the 1.0-2.5 classification group and 21.67±1.37 years for the 3.0-4.5 classification group. The low classification (1.0-2.5) group had a mean weight of 54.85±3.87 kg and a mean height of 1.56±0.09 m. High classified (3.0-4.5) women had a mean weight of 69.91±14.60 kg and a mean height of 1.68±0.15 m. Wingspans were calculated as 1.62±0.09 m for the lower class (1.0-2.5) and 11.69±0.12 m for the higher class (3.0-4.5). Mean body fat percentages for the women were 42.13±6.65 percent for the 1.0-2.5 class and 37.31±7.25 percent for the 3.0-4.5 class.

Table 1. *Participant Data*

Gender	Classification Group	Age (yr)	Weight (kg)	Height (m)	Wingspan (m)	Body Fat (%)
Men (n=13)	1.0-2.5 (n=8)	21.63±2.83	74.49±25.07	1.69±0.33	1.74±0.24	26.65±12.48
	3.0-4.5 (n=5)	25.75±4.03	82.83±6.62	1.76±0.11	1.81±0.09	26.99±5.01
Women (n=11)	1.0-2.5 (n=5)	23.00±7.35	54.85±3.87	1.56±0.09	1.62±0.09	42.13±6.65
	3.0-4.5 (n=6)	21.67±1.37	69.91±14.60	1.68±0.15	1.69±0.12	37.31±7.25

Strength Testing

According to Table 2, the men in the lower class (1.0-2.5) group had a mean handgrip strength of 42.05±5.42 kg for the right hand and 42.67±7.22 kg for the left. The 1-repetition maximum bench press mean was 203.75±54.43 pounds. The higher class (3.0-4.5) group had a mean handgrip strength of 41.93±7.07 kg for the right hand and 45.13±15.55 kg for the left. The 1-repetition maximum bench press mean was calculated at 228.75±46.08 pounds.

The lower class (1.0-2.5) women had a mean handgrip strength of 25.00±5.83 kg for the right hand and 23.60±6.65 kg for the left hand. For this group, the 1-repetition maximum bench press mean was 103.00±9.75 pounds. Women in the higher classification (3.0-4.5) group had a mean handgrip strength of 25.72±5.62 for the right hand and 28.00±5.64 for the left. The 1-repetition maximum bench press for this group was 135.20±19.69 pounds.

Table 2. *Strength Testing Data*

Gender	Classification Group	Handgrip Strength Right (kg)	Handgrip Strength Left (kg)	1RM Bench Press (lb)
Men (n=13)	1.0-2.5(n=8)	42.05±5.42	42.67±7.22	203.75±54.43
	3.0-4.5(n=5)	41.93±7.07	45.13±15.55	228.75±46.08
Women (n=11)	1.0-2.5(n=5)	25.00±5.83	23.60±6.65	103.00±9.75
	3.0-4.5(n=6)	25.72±5.62	28.00±5.64	135.20±19.69

Kinovea Video Analysis

According to the video analysis Table 3a, the mean 15 ft for lower class (1.0-2.5) men was 2.25±0.15 seconds. The 20 m time was 5.74±0.30 seconds. The mean number of pushes for the 15 ft distance was 5.71±0.76 pushes and the 20 m distance had a mean of 13.29±2.21 pushes. The higher class (3.0-4.5) group had a 15 ft mean time of 2.07±0.09 seconds, a 20 m mean time of 5.89±0.28 seconds, a mean number of pushes of 5.00±0.63 pushes for the 15 ft distance, and 13.17±1.94 pushes for the 20 m distance.

Table 3a displays the means for the women in the low class (1.0-2.5) 15 ft time as 2.36±0.11 seconds and 5.89±0.28 seconds for the 15 ft distance. The mean number of pushes for the 15 ft distance was 6.00±0.00 pushes and 13.17±1.94 for the 20 m distance.

Table 3b shows the means for the degrees of trunk and elbow flexions. For low class (1.0-2.5) men, a mean angle of 49±14 degrees was calculated for the initial trunk flexion and a mean angle of 56±12 degrees was determined for the trunk flexion. Initial elbow flexion had a mean of 98±8 degrees while the elbow flexion was 102±8 degrees. The higher class (3.0-4.5) men had a mean of 54±7 degrees of trunk flexion and 60±16 degrees of initial trunk flexion. The initial elbow flexion mean for this group was 101±10 degrees and 105±13 degrees for elbow flexion.

The women in the lower classification (1.0-2.5) group had a mean initial trunk flexion of 45±7 degrees and a mean of 60±7 for trunk flexion. The mean for initial elbow flexion was 99±8 degrees and 111±6 degrees for the elbow flexion. Women in the higher class (3.0-4.5) had a mean initial trunk flexion of 49±7 degrees and a mean of 53±4 degrees for trunk flexion. For this group, the mean was 99±8 degrees for initial elbow flexion and 105±13 degree for elbow flexion.

The contact and recovery times (sec) were recorded in Table 3c. For the men's lower classification (1.0-2.5) group, mean initial contact time was 0.44±0.11 seconds and 0.20±0.04 seconds for contact time. Initial recovery time and recovery time had means of 0.21±0.06 and 0.23±0.06, respectively. The high class (3.0-4.5) group had a mean initial contact time of 0.45±0.17 seconds and a mean contact time of 0.22±0.04 seconds. The mean for initial recovery time was 0.19±0.01 seconds, with a mean recovery time of 0.21±0.02 seconds.

The women's lower classification (1.0-2.5) group had a mean initial contact time of 0.46±0.08 seconds and a mean contact time of 0.26±0.01 seconds. Initial recovery time and recovery time means for this group was 0.19±0.04 and 0.25±0.03, respectively. The 3.0-4.5 classification group for the women had a mean initial contact time of 0.51±0.12 seconds. The contact time was recorded as 0.22±0.02 seconds. The mean for initial recovery time was calculated at 0.25±0.05 seconds and 0.26±0.03 seconds for recovery time.

Table 3a. *Kinovea Analysis of Sprint Times (Sec) and Number of Pushes*

Gender	Classification Group	15 ft Time (sec)	20 m Time (sec)	15 ft Pushes	20 m Pushes
Men (n=13)	1.0-2.5(n=8)	2.25±0.15	5.74±0.30	5.71±0.76	13.29±2.21
	3.0-4.5(n=5)	2.07±0.09	5.36±0.23	5.50±0.58	12.50±1.29
Women (n=11)	1.0-2.5(n=5)				
	3.0-4.5(n=6)				

Table 3b. *Kinovea Analysis of Trunk and Elbow Flexions (°)*

Gender	Classification Group	Initial Trunk Flexion (°)	Trunk Flexion avg (°)	Initial Elbow Flexion (°)	Elbow Flexion avg (°)
Men (n=13)	1.0-2.5(n=8)	49±14	56±12	98±8	102±8
	3.0-4.5(n=5)	60±16	54±7	111±12	113±6
Women (n=11)	1.0-2.5(n=5)	45±7	60±7	99±8	111±6
	3.0-4.5(n=6)	49±7	53±4	101±10	105±13

Table 3c. *Kinovea Analysis of Contact and Recovery Times (Sec)*

Gender	Classification Group	Initial Contact Time (sec)	Contact Time (sec)	Initial Recovery Time (sec)	Recovery Time (sec)
Men (n=13)	1.0-2.5(n=8)	0.44±0.11	0.20±0.04	0.21±0.06	0.23±0.06
	3.0-4.5(n=5)	0.45±0.17	0.22±0.04	0.19±0.01	0.21±0.02
Women (n=11)	1.0-2.5(n=5)	0.46±0.08	0.26±0.01	0.19±0.04	0.25±0.03
	3.0-4.5(n=6)	0.51±0.12	0.22±0.02	0.25±0.05	0.26±0.03

Correlations

According to the correlations (Table 4) calculated from participants' strength testing, and video analysis data, the strongest relationships for the male players in the lower classification group (1.0-2.5) were between handgrip strength and the 15 ft time (R: r=-0.89; L: r=-0.81). Handgrip strength had a strong influence on 20 m sprint times as well (R: r=-0.75; L: r=-0.93). An additional correlation was found between the 15 ft time and the initial elbow flexion (r=0.75). Body fat percentage (r=0.88), 1-repetition maximum bench press (r=-0.75)), trunk flexion (r=0.70), elbow flexion (r=-0.83), and initial elbow flexion (r=0.71) resulted in faster 15 ft sprint times for women in the lower classification group (1.0-2.5). Faster 20 m times for this group were observed with lower body weight (kg) (r=1.00) and initial trunk flexion (r=0.82). For the higher classification groups, men with faster 15 ft times had lower body fat percentages (r=-0.74), and trunk flexion (r=0.78), initial elbow flexion (r=0.85). The 20 m time was affected by the players' left handgrips (r=0.72), body fat percentage (r=-0.78), and initial elbow flexion (r=0.81). Strong correlations were not determined for women in the high classification (3.0-4.5) group. However, moderate correlations were observed between trunk flexion and 15 ft time (r=0.62), and initial trunk and elbow flexions and 20 m times (trunk: r=0.63; elbow: r=0.65).

Table 4. *Correlations*

Gender	Classification	Variables	Correlation
Men (n=13)	1.0-2.5(n=8)	20 m time (sec) and handgrip (L)	r=-0.93
		15 ft time (sec) and handgrip (R)	r=-0.89
		15 ft time (sec) and handgrip (L)	r=-0.81
		20 m time (sec) and handgrip (R)	r=-0.75
		15 ft time (sec) and initial elbow flexion (°)	r=-0.75
	3.0-4.5(n=5)	15 ft time (sec) and initial elbow flexion (°)	r=-0.85
		20 m time (sec) and initial elbow flexion (°)	r=0.81
		15 ft time (sec) and trunk flexion (°)	r=0.78
		20 m time (sec) and body fat (%)	r=0.78
		15 ft time (sec) and body fat (%)	r=0.74
		20 m time (sec) and handgrip (L)	r=0.72
Women (n=11)	1.0-2.5(n=5)	20 m time (sec) and weight (kg)	r=1.00
		15 ft time (sec) and body fat (%)	r=0.88
		15 ft time (sec) and elbow flexion (°)	r=0.83
		20 m time (sec) and initial trunk flexion (°)	r=0.82
		15 ft time (sec) and 1RM bench press (lb)	r=0.75
		15 ft time (sec) and initial elbow flexion (°)	r=0.71
		15 ft time (sec) and trunk flexion (°)	r=0.70
	3.0-4.5(n=6)	20 m time (sec) and initial elbow flexion (°)	r=0.65
		20 m time (sec) and initial trunk flexion (°)	r=0.63
		15 ft time (sec) and trunk flexion (°)	r=0.62

DISCUSSION

This study aimed to identify specific factors that strongly contributed to a collegiate wheelchair basketball's speed in order to provide wheelchair basketball coaches and players specific player data as well as fitness aspects players need to focus on to improve their quality of play. This study focused on the first 15 ft or 4.57 m of a maximum effort 20 m sprint to observe the player's movements during the initiation of their sprint. This movement is observed most often during play with changes, in direction, chasing an opponent, or breaking away from a defender. These scenarios depend on a player's ability to quickly accelerate. Identifying influential factors for this initial action could provide applicable information to coaches and players to improve their sprinting technique.

Overall, stronger correlations were established for the lower classification groups (1.0-2.5) for both men and women. Handgrip strength and elbow flexion were especially important for the male players' sprint times while elbow flexion and body fat percentage affected the sprint times for the female players. The higher classification group (3.0-4.5) males were more influenced by body fat percentage, trunk flexion, and initial elbow flexion. The moderate correlations for the women in the higher classification group correspond with the findings of the other groups with trunk and elbow flexions having the strongest effects on the sprint times. Lower classified players were able to push their wheels with more force, especially for the 15 ft time, due to the increased grip strength. The handgrip test measured the forceful flexion of all finger joints with the maximum voluntary force exerted by the subject. This force is placed on the wheel at the beginning of a push. The stronger the force, the harder the wheel is pushed, propelling the player to move faster across the floor.

In addition to handgrip strength, elbow flexion and body fat percentage had a strong influence on the lower classification sprint times. Higher classification males were also affected by body fat percentage. A player with a lower body fat percentage could get his or her trunk more parallel to the floor, achieving greater trunk flexion. Greater trunk flexion inherently activates triceps extension increasing the force on the wheel as the player pushes. Both higher classification males and females had faster sprint times depending on their trunk and elbow flexion. By definition of the Functional Classification system, players with higher classifications are more stable[5,9,17] and are able to utilize a seating position that allows for more range of motion of the trunk. This is consistent with previous work by Yanci et al who demonstrated that seating position can play a significant role in the ability to generate power during the initial push of wheelchair propulsion.[10] Players with lower classifications (in other words, less functional capacity) tend to sit in a position that puts their knees higher than their hips. This provides more stability, but adversely affects trunk range of motion, and therefore limits the ability of the athlete to use their trunk in the generation of power. Overall, elbow flexions strongly influenced the players' sprint times. The degree of elbow flexion depended on the contact angle on the player's wheel. The larger degree of elbow flexion allowed the player to reach further back on their wheel. A grip farther back on the wheel resulted in greater contact time on the wheel during the player's push, covering more distance faster with a single push. This ultimately results in a faster sprint time. Triceps strength has long been known to contribute to force application during wheelchair propulsion,6 and the findings that greater elbow flexion that allows for greater contact time on the wheel resulted in faster sprint times supports this notion.

LIMITATIONS

Potential limitations in this study could result from the grouping of the participants. Due to the small number of participants, subjects were placed into only two classification groups: low (1.0-2.5) and high (3.0-4.5). Different correlations may be determined if subjects were placed in more explicit groups to obtain more accurate and specific group data. This will allow for further comparison of data to determine trends in correlations between groups. It would be helpful if there were more subjects for each gender to be able to separate participants into more distinct groups. Additionally, one of the subjects in the lower classification group was classified lower due to limb length discrepancies rather than deficiencies in trunk function. The nature of the functional classification system allows for the deduction of classification points if the player is disadvantaged due to a number of reasons (limb length discrepancies, range of motion deficiencies, etc.), therefore this system in isolation is not always an indicator of trunk function. Due to the small subject size this may have skewed the results of the lower classification group with regard to several variables.

Additionally, this study did not differentiate between active and passive trunk flexion. Players with lower functional classifications often do not have the ability to actively bring their trunk back up to a seated position without using their hands,17 suggesting that any initial trunk flexion is passive in these players. Future studies should examine the role of active *vs* passive trunk flexion in wheelchair propulsion.

Further research should be completed to determine stronger correlations for female collegiate wheelchair basketball players with higher classifications (3.0-4.5). While strong correlations were not found for this group in this study, moderate correlations of the trunk flexion for the 15 ft time (r=0.62), and the initial trunk and elbow flexions on the both the 15 ft and 20 m times were identified during this study. Based on the correlations associated with trunk flexion, it may be helpful to investigate the effects of back and abdominal strength on a wheelchair basketball player's speed using an abdominal or back strength test.

Future studies may find additional results if the entire 20 m push, rather than the first 15 ft (4.57 m), is video-recorded. Video analysis of the entire 20 m distance can provide additional correlations or data trends for a maximal effort push. An improvement in sprint times may be observed if subjects are asked to complete a few practice sprints to warm up before the recorded sprint. The practice sprints will allow the participants to get a feel for how long the distance is and how hard to push to perform the fastest sprint possible with maximum effort.

PRACTICAL IMPLICATIONS

Workout and training programs should encourage shoulder flexibility and increasing the range of motion in the shoulder joint to allow the player to reach further back on the wheel of their sports chair. Additionally, coaches should encourage players to get their torsos as parallel to the floor as possible when sprinting to assist in creating a greater degree of elbow flexion.

CONCLUSION

This study has identified certain variables that can affect a wheelchair basketball player's speed. Initial elbow flexion was a moderate to strong correlation for both men and women as well as both the low and high classification groups. The results of this study can be shared with collegiate wheelchair basketball coaches and players to provide guidance in how to improve a player's ability for optimal sprinting.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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