Original Article

The effect of upper limb characteristics on palm strength, anaerobic power, and technical skills of wheelchair basketball players of varying classification

EMMANOUIL ZACHARAKIS¹

¹Faculty of Physical Education and Sports Science, National and Kapodistrian University of Athens
GREECE

Published online: March 31, 2020

(Accepted for publication: January 31, 2020)

DOI:10.7752/jpes.2020.02086

Abstract:

Wheelchair basketball is one of the most popular team sports for athletes with physical disabilities. The athletes' performance appears to be affected by their anthropometric characteristics, especially those of the upper limbs, as well as by their palm strength in moving the wheelchair. Comparable studies conducted with basketball players without disabilities have demonstrated that palm lengths and peripheries affect palm strength. The aim of this study was to examine the effect of upper limb characteristics on palm strength, anaerobic capacity, and technical skills of wheelchair basketball players of varying classification.

A total of 14 wheelchair basketball players participated in this study. Their anthropometric characteristics were measured, and a palm imprint was obtained to calculate palm lengths and peripheries. In addition, the athletes performed 8 tests of wheelchair propulsion and technical skills (5-m and 20-m sprint, lay-up, free throws, shots from four points, long pass, pass with accuracy, and dribbling). Lastly, their anaerobic power was assessed with a 30-s arm cranking test.

Palm lengths and peripheries did not have any effect on the subjects' handgrip strength and anaerobic capacity. However, right forearm length and right palm strength considerably affected the long pass. Moreover, the degree of disability was determined to affect certain skills such as the 5-m sprint, lay-up, and shots from four points

Key Words: wheelchair, basketball, upper limb, palm strength, anaerobic power, technical skills

Introduction

Wheelchair basketball is a popular sport for persons with physical disabilities (PPDs). In sports like basketball, which require dribbling, shooting etc., the length and muscles of the upper limb, combined with palm strength, play a very important role (Koley et al, 2011; Visnapuu & Jürimäe, 2007).

The wheelchair basketball players, in addition to having to use their skills in the game as do their counterparts without physical disabilities, are also burdened with moving their wheelchair. Upper limb characteristics (bone length and musculature) which affect handling the wheelchair and the ball play a key role in the athlete's correct and effective performance (Apostolidis & Zacharakis, 2015; Külünkoğlu et al, 2017).

Along these lines, a high correlation was found between finger length and palm strength; the longer the fingers, the greater the palm strength (Visnapuu & Jürimäe 2007; Koley, Singh & Kaur, 2011). Moreover, upper limb strength is important for better performance in wheelchair basketball players (Külünkoğlu et al, 2017; Akinoğlu & Kocahan, 2017).

Also, a significant correlation between the characteristics of the upper limbs, on the one hand, and speed and dribbling, on the other hand was observed (Apostolidis & Zacharakis, 2015). Regarding level of injury, which affect muscular recruitment, most studies have shown that athletes with high-level spinal injury produce inferior results in skill tests compared to those with low-level spinal injury or amputation (Vanlerberghe & Slock, 1987; Brasile, 1990; Brasile & Hendrick, 1996).

Despite the fact that technical characteristics of wheelchair basketball players (Bhambhani et al, 1995; Cooper et al, 1992; Hoffman, 1986; Janssen et al, 1993) as well as the forces which act when moving the wheelchair (Bergamini et al, 2015; Vanlandewijck et al, 1999; Vanlandewijck et al, 2001) plays an important role for better performance, there have been no studies dealing with the effect of anthropometric characteristics as a whole, especially the effect of upper limb strength and palm strength, (a) on moving the wheelchair, and (b) on using the technical skills required for the game.

The present study aims at ascertaining: (a) the effect of wheelchair basketball players' anthropometric characteristics on their technical skills; and (b) the effect of palm strength both on the athletes' anaerobic capacity and their technical skills.

Materials & Methods

Participants

The present study was performed with fourteen male volunteers, all of them Greek wheelchair basketball players (average age 40 ± 6.6 years). All of them were members of teams in the Championship of Greece and had been playing for at least two years. The athletes were classified from 1 to 4.5 according to the standards of the International Wheelchair Basketball Federation (IWBF); the highest the grade, that highest the person's functional ability. Athletes with a grade between 1 and 2.5 are considered low-class athletes with heavy disability, as they usually have an injury in a high point of their spine. In contrast, athletes with a classification of 3 to 4.5 are considered high-class athletes with light disability, as they have an injury in a low point of their spine or have undergone lower limb amputation. Most studies agree on the fact that the level of disability substantially affects the results of the tests (Bhambhani, 2002; Bhambhani et al, 1994; Hopman et al, 1992; Veeger et al, 1989).

The test subjects were divided into two groups, according to their IWBF classification: (a) high-level injured athletes, i.e. with a high classification grade (3-4.5, $n = 7$), and (b) low-level injured athletes, i.e. with a low classification grade (1-2.5, $n = 7$).

The athletes' anthropometric characteristics were recorded, and they were subjected to eight tests for assessing their ability both to move the wheelchair (5-meter and 20-meter sprint) and to perform the basic skills required for the game (dribbling, shots, passes, etc.). All tests were conducted in an indoor basketball court. The subjects subsequently performed a test for determining their anaerobic capacity in a steady ergometer especially adapted for wheelchairs.

Measurements

Anthropometric Characteristics

The following anthropometric characteristics were recorded:

I. Body height and sitting height

Due to their inability to stand, the athletes lay supine on a mat, and their height was measured. There followed a measurement in the seated position. The subjects were seated on a stool placed in front of the perpendicular surface of a wall. Sitting height was measured with a measuring tape to the nearest centimeter, from the highest point of the cranium to the base sitting surface. For the top of the cranium to reach the highest possible point, the subject must keep their head at the horizontal conchal-acoustic level and sit in a way so that their hips, shoulder blades, and occipital bone touch the surface of the wall.

II. Body weight

The subjects' weight was measured in the seated position, using accurate scales (Bilance Salus, Milano). Due to their inability to stand, the athletes were seated on a square 4.5-kg wooden box placed on the scales. The weight of the box was subsequently subtracted from the total measured weight.

III. Right palm imprint

Every athlete placed his hand on a white sheet of paper, opening his fingers as wide as possible, and his palm was imprinted by the researcher (Fig. 1). The calculation of the palm's lengths and peripheries was based on the method by Visnapuu & Jürimäe (2007).

Figure 1. Test subject palm imprint for measuring the palm's lengths and peripheries (W = wrist, T = thumb, I = index finger, M = middle finger, R = ring finger, L = little finger)

IV. Arm and forearm length

Arm length was measured from the tip of the acromion to the highest point of the head of the radius. Forearm length was measured from the highest point of the head of the radius to the furthest point of the radial styloid process (Norton et al, 1996). The measurement was made using an elastic tape of accuracy ± 0.1 cm (220 Seca, Germany).

Handgrip strength

The left and right palm strength was measured with a hand dynamometer (Grip-D, Japan). The test subject sat in his wheelchair with his hand loosely dangling, next to the wheel. His other hand, the one not holding the dynamometer, should not be resting on the wheelchair or on his torso. Each athlete had a set of three attempts; the

first one was a trial, the next two were recorded for the measurement. The best effort was the subject's final grade in this measurement.

Skill evaluation tests:

The following eight tests were conducted, which determine the technical skills of wheelchair basketball players.

(i) & (ii) 5-meter and 20-meter sprint

In both of these tests speed was calculated on the basis of the time the subject took to cover the set distance. The subject takes his position behind the baseline of the basketball court. They set off at the researcher's signal and cover the set distance [5 meters for (i); 20 meters for (ii)] as fast as they can. The time taken is recorded in seconds (Brower USA photocells were used in all tests where time is the score).

(iii) Free throws

The subject shoots 20 free shots in four sets of 5 shots each. They take a one-minute interval between sets. The score is the total of successful shots.

(iv) Dribbling

The subject maneuvers through a series of obstacles, as fast as they can, moving the wheelchair and dribbling according to the IWBF regulations (Fig. 2). The subject finishes by moving his wheelchair behind the starting line, before the first obstacle. The procedure is repeated once more in the same way, without a break. For every violation of the dribbling regulations, 5 seconds are added to the total time of the performance. During the test, every time the ball or the subject's wheelchair come to contact with an obstacle, 1 second is added to the total time of the performance. Every time the subject loses ball possession they have to restart at the point of loss and continue to the end of the procedure. Every subject is entitled to a trial attempt in order to familiarize himself with the procedure. The score is the total time of performance of both rounds.

Figure 2. Schematic representation of the dribbling test

(v) Lay-up

For this test, two cones must be placed on the extrapolated key lines, at a distance of 6.25 meters from the baseline. The subject is positioned below the center of the ring. At the researcher's signal, he performs as many lay-ups as he can in two minutes. After each attempt, he claims the ball himself and moves his wheelchair to the opposite cone with the ball, in order to start the next attempt. The score is the total of attempts plus the total of successful attempts.

(vi) Long pass

The subject positions his wheelchair with the front wheels just behind the court's baseline and tries to send the ball as far as he can with a chest pass. Each one has six attempts. The distance is measured in meters, and the score is the longest distance covered.

(vii) Pass with accuracy

For this test, three concentric rectangles of different sizes are drawn on a smooth wall to serve as targets (Fig. 3). The subject positions their wheelchair behind a line at a distance of 9.14 m. from the target, for baseball players with a classification grade of 2 to 4.5, and at 7.62 m. from the target, for baseball players with a classification grade of 1 and 1.5. At the researcher's signal, the subject performs 10 passes in any way he wants (with both hands, with one hand, reverse, overhead, etc.). Making the ball bounce on the ground before it hits the target is not allowed. The subject gets (a) 3 points (the highest score) if the ball hits the inner (smaller) rectangle or any of its sides; (b) 2 points if the ball hits the middle rectangle or any of its sides; and (c) 1 point if the ball hits the outer rectangle or any of its sides. If the ball does not hit any of the targets, the subject gets 0 points for this attempt. The subjects are entitled to three trial attempts and they may never cross the shooting line.

Figure 3. *Pass with accuracy: target layout (all lengths in centimeters)*

(viii) Shots from four spots

Four shooting points are marked on the ground around the basket, at a distance of 4 meters from the center of the ring and at angles of 45° and 60° to the basket (Fig. 4). The subject has two attempts of 60 seconds each. The subject stands behind the first point of 45°. At the researcher's signal he shoots, reclaims the ball and shoots again from another point. He has to shoot from all four points successively and then, if there is any time left, he must choose which points he will shoot again from. Timing begins with the subject's first throw. Violations/penalties: In case of traveling, the successful shot does not count and the subject gets 0 points. In case of two consecutive shots from the same point, the second one, if successful, does not count and gets 0 points. Each successful shot gets 1 point. The better of the two attempts is the subject's score in this test.

Figure 4. *Schematic representation of shots from four points*

Evaluating maximal anaerobic power

Determining the appropriate individual workload

The protocol used for evaluating anaerobic capacity in athletes with physical disabilities is similar to the one for persons without physical disabilities. The subjects must perform a 30-second arm cranking with the greatest possible speed.

For the determination of the appropriate individual workload in evaluating maximal anaerobic power, the subjects turned up in the lab at least three hours after their most recent meal; if they were smokers, they had to have refrained from smoking for at least two hours before the onset of the procedure. After measuring their height and weight, their competition wheelchair was adjusted on the ergometer (VP Handi Tecmachine Medical Development, France). There was a 5-minute warm-up without workload, followed by a standard set of stretching exercises for the upper limbs. The warm-up was followed by the procedure of determining the individual workload to be applied during the anaerobic power test. The aim is to ensure that the workload applied during the test will result neither in overestimation nor underestimation of the maximal, minimal, and median anaerobic capacity of each person¹¹. More specifically, each subject performed five to seven 5-second attempts with a workload of 1-7 Nm, administered by the researcher in a random and compensatory order (Fig. 5). In between tests there was a rest period of 2 minutes, when the subject relaxed by stretching. In every 5-second attempt the maximal power produced was recorded. These attempts yielded the prediction equation of the relation between force and speed, which presented a high correlation percentage ($r = 0.75-0.95$) and accounted for a high percentage of the observed dispersion ($R^2 = 0.95-0.97\%$). In this way the maximal isometric force (F_{iso}) was obtained – the force which needs to be applied on the ergometer so that the subject cannot move the wheelchair.

The final selection of workload (P_{30}) applied on the subjects during the Wingate test was computed based on the equation $P_{30} = 0.51F_{iso} - 0.18$ ($R^2 = 0.75$), published by Janssen *et al.* (1993). Speed during the procedure never exceeded 3 m/sec, so as not to disturb the subjects' co-ordination of wheelchair movement and consequently the validity of the results (Dallmeijer *et al.*, 1996; Janssen *et al.*, 1993).

Figure 5. Indicative graphical reproduction of the prediction equation of a test subject's maximal isometric force for determining the individual workload in evaluating maximal anaerobic power

Statistical analysis

The statistical software SPSS 22 was used for data analysis. Correlation significance was measured using the Pearson correlation co-efficient. Subsequently, an Independent Samples t Test was performed in order to assess the differing results produced by test subjects with different classifications.

Results

The subjects' anthropometric characteristics, palm strength, and anaerobic capacity of the upper limbs are shown in Table I. Statistically significant differences between the two groups were recorded in height ($p = 0.03$), weight ($p = 0.01$), arm length ($p = 0.00$), and forearm length ($p = 0.00$). Differences in finger length and palm peripheries were statistically insignificant.

Table I. Anthropometric characteristics and anaerobic power of the upper limbs of high-class and low-class wheelchair basketball players

Tests	High-class athletes		Low-class athletes	
	Mean	SD	Mean	SD
Anthropometric characteristics				
HEIGHT	189.29*	9.34	180.86	5.73
SITTING HEIGHT	92.86	4.03	89.86	3.68
WEIGHT	89.57*	9.00	77.00	9.27
FOREARM	30.14*	0.69	28.29	1.35
ARM	41.29*	1.58	39.14	1.18
PALM PERIPHERIES	60.44*	2.27	62.50	2.78
RIGHT HANDGRIP	53.80	15.55	52.73	7.26
LEFT HANDGRIP	49.09	8.35	50.74	5.30
Anaerobic capacity				
MAXIMAL POWER (Watt)	237.86	28.39	219.43	37.71
MEDIAN POWER (Watt)	170.64	28.39	156.57	24.76
MINIMAL POWER (Watt)	141.51	29.37	119.29	13.19
FATIGUE INDEX (%)	40.43	7.78	44.91	7.09

* $p < 0,05$ – statistically significant differences

The technical skill tests were performed in a basketball court (Table II); statistically significant differences between the two groups were recorded in the 5-m. sprint ($p = 0.043$), lay-up ($p = 0.031$), and shooting ($p = 0.024$).

Table II. Technical skill tests of high-class ($n = 7$) and low-class ($n = 7$) wheelchair basketball players

Tests	High-class athletes		Low-class athletes	
	Mean	SD	Mean	SD
5-M SPRINT (sec)	1.94*	0.17	2.1	0.17
20-M SPRINT (sec)	5.77	0.51	6.02	0.33
FREE THROWS (set of 20 trials)	8.43	4.08	6.43	4.86
DRIBBLING (sec)	35.01	4.56	36.91	1.87
LAY-UP (1 m)	9.29*	1.7	6.71	2.56

PASS WITH ACCURACY (10 at)	16.29	3.09	16.14	3.58
LONG PASS (m)	10.84	1.74	9.64	1.83
SHOTS (1 m)	4.29***	1.98	2.57	0.98

* $p < 0.043$ **, $p < 0.031$ ***, $p < 0.024$ – statistically significant differences

The anatomical characteristics (palm lengths and peripheries) and handgrip strength did not correlate with the anaerobic power of the athletes in either group. A positive correlation was found between right handgrip strength and long pass ($r = 0,536$), and between arm length and long pass ($r = 0,535$). On the other hand, a negative correlation was found between the 5-m. sprint and lay-up ($r = -0,563$). The lay-up skill shows a positive correlation ($r = 0,551$) to the free-throw skill.

Discussion

The present study showed that palm lengths and peripheries didn't have any effect on the subjects' handgrip strength and anaerobic capacity. However, right forearm length and right palm strength greatly affected the long pass results. In addition, the degree of disability was found to affect certain skills like the 5-m. sprint, lay-up and shots from four points. Lastly, no differences were recorded in the anaerobic capacity of high-class and low-class athletes.

The present study showed that anthropometric characteristics of the upper arms has no effect on handgrip strength and anaerobic performance. Other studies have demonstrated a significant correlation between anthropometric characteristics and right and left palm strength (Koley, Singh & Kaur 2010). This is probably due to the athletes' disability, the high competition level of the Greek athletes, and the training schedule, given that the test subjects of the present study only trained twice or three times a week.

The results of the present study demonstrated that there was no statistically significant differences in anaerobic capacity between the two groups.

An important finding to emerge from the present study was that right handgrip strength and right arm length had a positive correlation to long pass. This one-sided correlation of the right side can be attributed to the fact that all athletes were right-handed, and both hands are mobilized for the long pass, the dominant side always plays a bigger part. Moreover, long pass results are further affected by finger strength. During the long pass only the fingers must touch the ball, the role of the palm being secondary. Therefore, when an athlete has stronger limbs than another, he is expected to score better in long pass.

Nevertheless, it seems that high-class athletes tend to have better results in the indices of anaerobic capacity of the upper limbs than low-class athletes, which may be due to the anatomical differences of the arm and forearm. Moreover, low classification because of greater disability was not shown to prevent athletes from developing their anaerobic capacity and all of its characteristics according to the sport's requirements, so long as their upper limb mobility allowed them to perform the technical skills required. The fact that low-class athletes also use their wheelchair in their everyday activities certainly contributed to that (Külünkoğlu et al, 2017).

A number of studies have dealt with recording the physical and technical characteristics of wheelchair basketball players (Bhambhani et al, 1995; Cooper et al, 1992; Hoffman, 1986; Janssen et al, 1994) and the forces which act when moving the wheelchair (Bergamini et al, 2015; Vanlandewijck et al, 1999; Vanlandewijck et al, 2001). However, there are not many studies examining the overall effect of anatomical characteristics, upper limb strength, and palm strength on moving the wheelchair, on the technical skills required for the game, and on the subjects' maximal anaerobic capacity.

Previous research conducted with basketball players without disabilities has demonstrated that upper limb strength and palm strength have a positive effect on certain basketball technical skills (Apostolidis & Zacharakis, 2015; Visnapuu & Jürimäe, 2007).

Although the protocol used for the assessment of the anaerobic capacity is similar among the athletes with or without physical disabilities (workload application for a 30-second session with the fastest possible speed), there is no agreement on the appropriate resistance that should be applied when examine athletes with physical disabilities (Janssen et al, 1993; Janssen et al, 1994; Lin et al, 1993; Rotstein et al, 1994; Veeger et al, 1992). The different types of disability and the variety of testing equipment used make it difficult to implement a standard protocol for measuring the anaerobic capacity of people with physical disabilities.

In particular, as regards the choice of the ergometer, Bhambhani (2002), van der Woude et al (1997) and van der Woude et al (1998) support that ergometers selected by the researchers are: a) arm cranking b) computerized stationary wheelchair ergometer (WERG); (c) wheelchair mounted on a treadmill (WCT); and (d) wheelchair mounted on rollers (WCR). Due to the lower muscle mass participation during exercise in people with physical disabilities, a workload application exclusively related to the body weight of the participant, is extremely risky and usually leads to fictitious data.

Moreover, the level of anaerobic capacity performance using WAT system, is inversely proportional to the level of the spinal cord injury. As a result, the higher in the spinal column the injury happens, the lower the anaerobic power of the tested participant (23 to 46 W for quadriplegics and 57 to 336 W for paraplegics and athletes with amputation).

A number of factors also influence the measurement of anaerobic capacity in PPDs. Bhambhani (2002), in a review regarding anaerobic capacity in PPDs, concludes that, (a) most studies have a limited number of test subjects; (b) certain studies perform statistical analysis among persons with different types of disability, which makes it harder to assess the results; (c) the degree of spinal cord injury significantly affects biological reactions, thus confusing result assessment, (d) differences in the test protocols used make it difficult to compare findings; and (e) most studies have been carried out with males, studies with females are quite few.

Finally, in their research with basketball players without disabilities, Apostolidis & Zacharakis (2015) demonstrated a high correlation of upper limb characteristics to sprint and dribbling, whereas the present study, in assessing the technical skills of wheelchair basketball players, demonstrated a negative correlation between sprint and lay-up. The faster the players perform a test, the more likely they are to get an unsuccessful shot. A successful shot in wheelchair basketball depends as much on the player's shooting skill as on their ability to control the competition wheelchair. The present study demonstrated a positive correlation between free throws and lay-up. Consequently, players with a good shooting technique during free shots are normally expected to score equally well during lay-ups.

The results were probably influenced by the small size of the sample group, the subjects' advanced age, their amateurism, and the fact that most subjects did not practice basketball or any other sports prior to their injury.

Conclusions

The results of the present study are in agreement with those of other studies regarding the differences in technical skills between high-class and low-class athletes. Athletes with heavy disabilities scored worse in most tests concerning technical skills and wheelchair propulsion.

On the other hand, bone length of the upper limbs, as well as palm lengths and peripheries did not seem to significantly affect the subjects' handgrip strength and anaerobic capacity. Moreover, no differences were recorded in anaerobic capacity between high-class and low-class athletes.

These results were probably influenced by the small size of the sample group, the subjects' advanced age, their amateurism, and the fact that most subjects did not practice basketball or any other sports prior to their injury.

Any future research on the subject would best be conducted with a bigger sample group, consisting of athletes of a younger age and higher standards.

References

- Akinoğlu, B., Kocahan, T. (2017). Characteristics of upper extremity's muscle strength in Turkish national wheelchair basketball players team. *J Exerc Rehabil*, 28, 13(1), 62-7.
- Apostolidis, N., & Zacharakis, E. (2015). The influence of the anthropometric characteristics and handgrip strength on the technical skills of young basketball players. *Journal of Physical Education and Sport*, 15 (2), 330-7.
- Bhambhani, Y. (2002). Physiology of wheelchair racing in athletes with spinal cord injury. *Sports Med*, 32, 23-51.
- Bhambhani, Y.N., Burnham, R.S., Wheeler, G.D., Eriksson, P., Holland, L.J., & Steadward, R.D. (1995). Physiological correlates of simulated wheelchair racing in trained quadriplegics. *Can J Appl Physiol*, 20, 65-77.
- Bhambhani, Y.N., Holland, L.J., Eriksson, P., & Steadward, R.D. (1994). Physiological responses during wheelchair racing in quadriplegics and paraplegics. *Paraplegia*, 32, 253-60.
- Bergamini, E., Morelli, F., Marchetti, F., Vannozzi, G., Polidori, L., Paradisi, F., et al. (2015). Wheelchair propulsion biomechanics in junior basketball players: a method for the evaluation of the efficacy of a specific training program. *BioMed Research International*, 2015: 275965.
- Brasile, F. (1986). Do you measure up? *Sports 'n Spokes*, 12 (4), 43-7.
- Brasile, F. (1990). Performance evaluation of wheelchair athletes: more than a disability classification level issue. *Adapted Physical Activity Quarterly*, 7, 289-97.
- Brasile, F. (1993). Evaluation of the elite. *Sports 'n Spokes*, 19 (3), 52-5.
- Brasile, F. (1996). Wheelchair basketball skills proficiencies versus disability classification. *Adapted Physical Activity Quarterly*, 3, 6-13.
- Brasile, F., & Hendrick, B. (1996). The relationship of skills of elite wheelchair basketball competitors to the international functional classification system. *The Recreate Journal*, 30, 114-27.
- Cooper, R.A., Horvath, S.M., Bedi, J.F., Drechsler-Parks, D.M., & Williams, R.E. (1992). Maximal exercise response of paraplegic wheelchair road racers, *Paraplegia*, 30, 573-81.
- Dallmeijer, A.J., Hopman, M.T., van As, H.H., & van der Woude, L.H. (1996). Physical capacity and physical strain in persons with tetraplegia; the role of sport activity. *Spinal Cord*, 34, 729-35.
- Hoffman, M.D. (1986). Cardiorespiratory fitness and training in quadriplegics and paraplegics. *Sports Medicine*, 3 (5), 312-30.
- Hopman, M.T., Oeseburg, B., & Binkhorst, R.A. (1992). Cardiovascular responses in paraplegic subjects during arm exercise. *Eur J Appl Physiol Occup Physiol*, 65, 73-8.
- Hutzler, Y. (1998). Anaerobic fitness testing of wheelchair users. *Sports Med*, 25, 101-13.

- Hutzler, Y., Grunze, M., & Kaiser, R. (1995). Physiological and dynamic responses to maximal velocity wheelchair ergometry. *Adapt Phys Activity Q*, 12, 344-61.
- Hutzler, Y., Ochana, S., Bolotin, R., & Kalina, E. (1998). Aerobic and anaerobic arm-cranking power outputs of males with lower limb impairments: relationship with sport participation intensity, age, impairment and functional classification. *Spinal Cord*, 36, 205-12.
- Hutzler, Y., Vanlandewijck, Y., & van Vlierderghe, M. (2000). Anaerobic performance of older female and male wheelchair basketball players in a mobile wheelchair ergometer. *Adapt Phys Activity Q*, 17, 450-65.
- Janssen, T.W., van Oers, C.A., Hollander, A.P., Veeger, H.E., & van der Woude, L.H. (1993). Isometric strength, sprint power, and aerobic power in individuals with a spinal cord injury. *Med Sci Sports Exerc*, 25, 863-70.
- Janssen, T.W., van Oers, C.A., van der Woude, L.H., & Hollander, A.P. (1994). Reliability of heart rate responses to non-steady-state activities of daily living in men with spinal cord injuries. *Scand J Rehabil Med*, 26, 71-8.
- Koley, Sh., Singh, J., & Kaur, S. (2010). A study of arm anthropometric profile in Indian inter-university basketball players. *Journal of Human Sports and Exercise*, 5, 389-99.
- Koley, Sh., Singh, J., & Kaur, S. (2011). A study of arm anthropometric profile in Indian inter-university basketball players. *Journal of Sports Sciences*, 5 (1), 35-40.
- Külünkoğlu, B., Akkubak, Y., & Ergun, N. (2017). The profile of upper extremity muscular strength in female wheelchair basketball players: a pilot study. *J Sports Med Phys Fitness*, doi: 10.23736/S0022-4707.17.06862-1.
- Lin, K.H., Lai, J.S., Kao, M.J., & Lien, I.N. (1993). Anaerobic threshold and maximal oxygen consumption during arm cranking exercise in paraplegia. *Arch Phys Med Rehabil*, 74, 515-20.
- Norton, K., Whittingham, N., Carter, L., Kerr, D., Gore, C., & Marfell-Jones, M. (1996). Measurement techniques in anthropometry. In *Anthropometrica*, eds K. Norton & T. Olds, pp. 25-75. Sydney: University of New South Wales Press.
- Rotstein, A., Sagiv, M., Ben-Sira, D., Werber, G., Hutzler, J., & Annenburg, H. (1994). Aerobic capacity and anaerobic threshold of wheelchair basketball players. *Paraplegia*, 32, 196-201.
- Tsukagoshi, K.M., Lida M., Kamikozuru, et al. (1994) A method for determining maximal anaerobic power in wheelchair users. 3rd International Congress of the Asian Society for Adapted Physical Education and Exercise; Oct 22-23: Taipei
- van der Woude, L.H., Bakker, W.H., Elkhuisen, J.W., Veeger, H.E., & Gwinn, T. (1997). Anaerobic work capacity in elite wheelchair athletes. *Am J Phys Med Rehabil*, 76, 355-65.
- van der Woude, L.H., Bakker, W.H., Elkhuisen, J.W., Veeger, H.E., & Gwinn, T. (1998). Propulsion technique and anaerobic work capacity in elite wheelchair athletes: cross-sectional analysis. *Am J Phys Med Rehabil*, 77, 222-34.
- Vanlandewijck, Y.C., Daly, D.J., & Theisen, D.M. (1999). Field test evaluation of aerobic, anaerobic, and wheelchair basketball skill performances. *Int J Sports Med*, 20, 548-54.
- Vanlandewijck, Y.C., Theisen, D.M., & Daly, D.J. (2001). Wheelchair propulsion biomechanics: implications for wheelchair sports. *Sports Med*, 31 (5), 339-67.
- Vanlerberghe, J.O.C., & Slock, K. (1987). A study of wheelchair basketball skills. In *International Perspectives of Adapted Physical Activity*, eds M. Berridge & G. Ward, pp. 221-32. Champaign, IL: Human Kinetics.
- Veeger, H.E., Lute, E.M., Roeleveld, K., & van der Woude, L.H. (1992). Differences in performance between trained and untrained subjects during a 30-s sprint test in a wheelchair ergometer. *Eur J Appl Physiol Occup Physiol*, 64, 158-64.
- Veeger, H.E., van der Woude, L.H., & Rozendal, R.H. (1989). Wheelchair propulsion technique at different speeds. *Scand J Rehabil Med*, 21, 197-203
- Visnapuu, M., & Jürimäe, T.V. (2007). Handgrip strength and hand dimensions in young handball and basketball players. *Journal of Strength and Conditioning Research*, 21 (3), 923-9.