BIOMECHANICS AND ADAPTED PHYSICAL ACTIVITY

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Several examples of biomechanical research work on Adapted Physical Activity are presented in this paper. In many cases, the same biomechanical analyses used in general sports activities can be applied to disability-based sports, as well. The methodology and the knowledge of biomechanics are expected to contribute to the development of competitive sports for the disabled, especially in the following aspects in the future:
(1) to analyze certain sports skills and to advise athletes how to improve their skill levels
(2) to develop and amend sports equipment and apparatus based on the motion analysis
(3) to support competitors in training to improve their physical fitness levels
(4) to advise and support for the functional classification of the athletes

KEY WORDS: adapted physical activity, disabled, wheelchair, Paralympic Games Twin Basketball, Sit-ski

Biomechanics for Special Population - What is "Special Population": Originally, the title of my paper was requested as "Biomechanics for special population". What is a "Special Population"?
When individual ability, mental or physical, can be expressed quantitatively and shows normal distribution as a population, an individual with an ability beyond average + 3 S.D. or below average – 3 S.D. could be considered "special". For example, when we think of running ability, such as the 100 m sprint time, both Olympic athletes and persons in wheelchairs with spinal cord injuries would be considered very "special". On the other hand, classroom or private instruction lesson programs designed for students whose learning needs cannot be met by a standard school curriculum are so called "special education". In this example, "special population" generally refers to persons disabled or handicapped either physically or mentally. In recent years these words have not been used often. Instead, "Adapted Physical Activity" or "Adapted Sports" are recognized and have been widely used. Though the words "Adapted Physical Activity" or "Adapted Sports" do not necessarily mean physical or sports activity only for disabled persons, the concept of the word "Adapt" refers to the theory and practice of adaptation of physical activities to the specific needs of disabled and sometimes elderly persons. Several examples of biomechanical research work on Adapted Physical Activity will be presented in this paper.

Relationship Between Exercise Duration and Power Output for Wheelchair Race: All energy sources for living body, including physical activity, is supplied by resolution of ATP (Adenosine Triphosphate) into ADP (Adenosine Diphosphate), and ATP should be continuously resynthesized through three processes, namely ATP-PC (or the phosphagen) stores, lactic acid (or anaerobic glycolysis) system, and oxydative (or aerobic respiration) system. These three systems are also called as high-power, middle-power, and low-power systems, respectively, according to the power output level for each system. In general, the longer the exercise duration, the lower the power the body can produce.
Figure 1 shows the relationship between the distance of track events and the average speed for world records, for both general runners and wheelchair racers. In contrast to the tendency of general runners (Olympians), the speed of wheelchair racers does not decrease as the exercise duration or race distance increases. One reason for this phenomenon could be that the wheelchair racers do not need large power exertion to maintain speed after they once reach the top speed. It also suggests that the maximum power output would be the most important factors in physical resources, for any wheelchair track events rather than middle or low power exertion abilities.

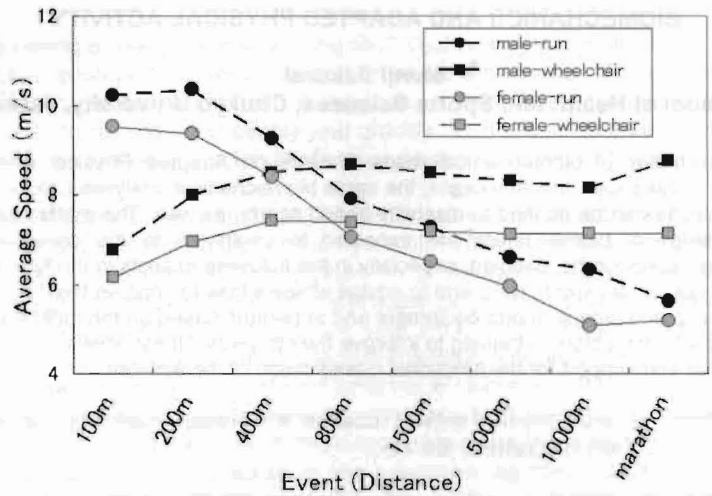

Figure 1 The relationship between the distance of track events and the average speed for world records, for both general runners and wheelchair racers

3-D Analysis of Alpine Sit-skiing in Winter Paralympic Games: Winter Paralympic Games was held in Nagano, just after the Winter Olympics 1998 at the same venue. It was the first Winter Paralympics held outside of Europe. There had been very few biomechanical studies on Winter Paralympic sports. In Nagano Paralympics, there were four events, namely Alpine skiing, Nordic skiing, ice sledge speed race and ice sledge hockey. As a part of IPCSSC (International Paralympic Committee Sport Science Committee) projects, we executed three-dimensional motion analysis of Alpine skiing.

In Alpine skiing, competitors with disabilities in both lower limbs use a sit-ski. A sit-ski consists of a seat and a single ski connected with a shock absorption device. Since gravity provides propulsion for downhill skiing, the primary requirement for any skier is the ability to support his or her own weight, either independently or by means of prosthetic and/or orthotic devices. Skiers control the sit-ski by shifting their weight and turning or braking with hand-held outriggers. In recent years, the development and research of the sit-ski device has advanced, but there are few studies on the skiers' performance during sit-skiing.

Seven female competitors using sit-skis participated in LW10-12 class of the slalom event. In Alpine ski slalom, it is important to pass the shortest distance between the poles with the minimum speed loss during the turn. During a right turn between the 22nd gate and the 23rd gate of the 1st run, their turning motions were recorded using two video cameras, which were placed in the audience stand on the side of the racing course (figure 2). The direct linear transformation (DLT) method was used to determine three-dimensional spatial coordinates of the points on the skier's body and the ski. Changes in the velocity of the center of the ski, angle of attack of the ski, lean and rotation angles of the upper torso were calculated.

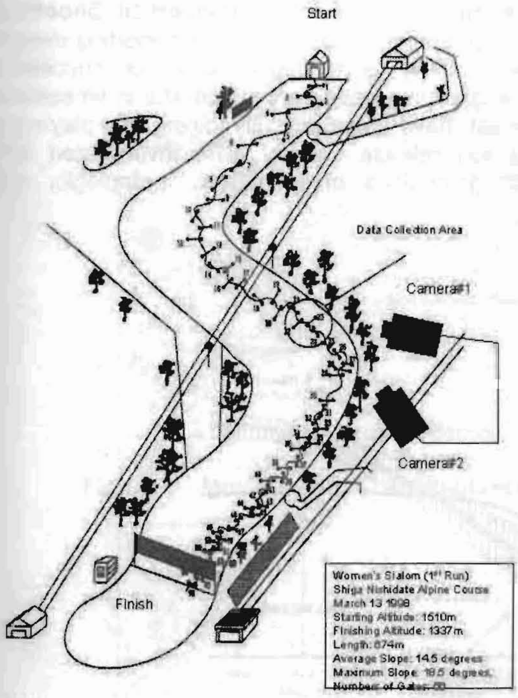

Figure 2 Outline of the slalom course

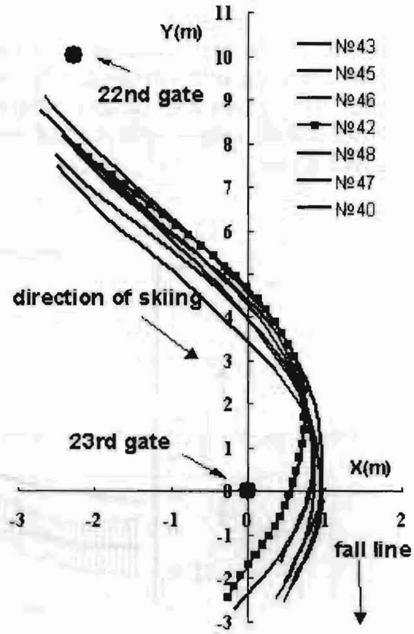

Figure 3 Track of the center of the ski on X-Y plane

Figure 3 shows the tracks of the center of the ski projected on the ski slope. It can be observed that skier No.42 changed the direction of the turn at the early phase and passed the nearest turn arc to the pole. As the delay in the timing of changing direction increased, the arc of the turn to the pole tends to be larger. Figure 4 shows the changes of the attack angle of the ski, angle between ski and the ski velocity vector. The attack angle of the slowest skier (No.40) was extremely larger than those of the other skiers in the latter half of the turn.
Smaller angle of attack, smaller upper torso lean and counter rotation of the upper torso are necessary for successful sit-ski turns, just as in the case of ordinary ski turns.

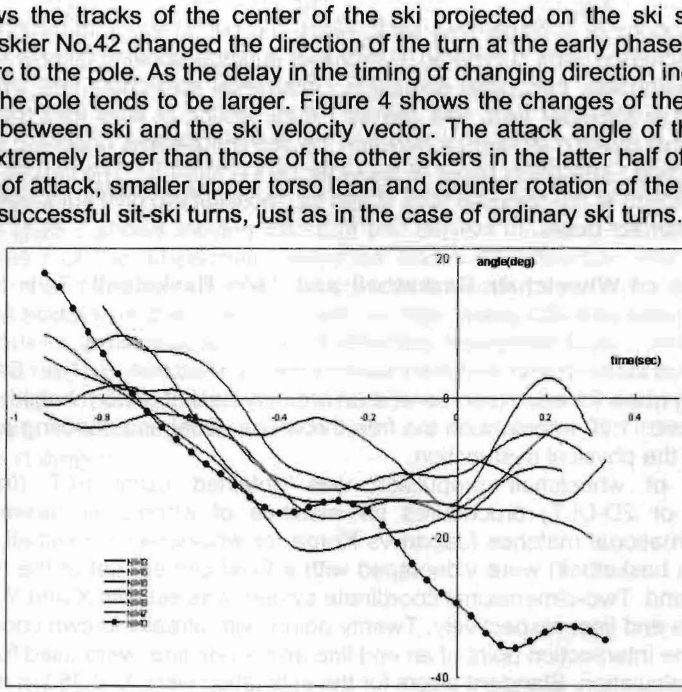

Figure 4 Changes in attack angle of the ski during a turn

A Kinematic Study of the Upper-Limb Motion of Wheelchair Basketball Shooting: Wheelchair basketball is one of the most popular sports for disability-based sporting events. For wheelchair basketball athletes shooting ability is a major factor for successful performance. In general, persons with paraplegia have been very successful in wheelchair basketball. Persons with tetraplegia, by contrast, have some difficulty joining and playing in this sport. The kinematic factors affecting ball release velocity were investigated with three-dimensional video analysis of shooting motions of tetraplegic, paraplegic, and able-bodied adults.

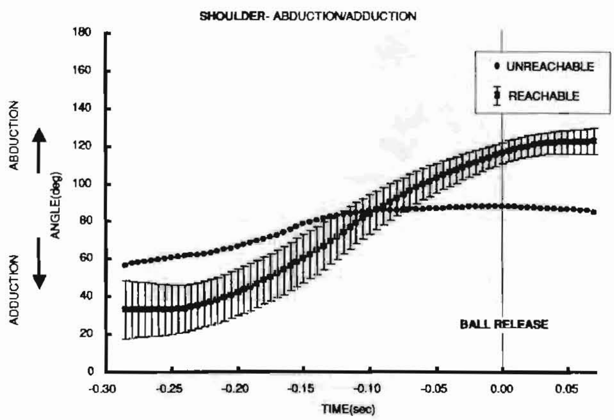

Figure 5 Comparison 0f the angle changes of abduction / adduction angle at shoulder between reachable and unreachable subjects

The shooting motions of subjects who could reach the ball to the goal (reachable) and who could not (unreachable) were compared. Reachable subjects showed greater range of motion in abduction / adduction, horizontal adduction / horizontal abduction, and internal rotation / external rotation at shoulder joint, and palmar / dorsi flexion at wrist joint than unreachable subjects. The most obvious difference between the two groups was observed in the changing pattern of abduction / adduction angle at shoulder joint (Figure 5). The results suggest that a large range of motion at the shoulder joint would be necessary to give sufficient kinetic energy to the ball to reach the goal.

Match Analysis of Wheelchair Basketball and Twin Basketball: Twin basketball was invented and developed 23 years ago in Japan. This sport is especially designed for tetraplegic persons. Most tetraplegic persons have some difficulties to shoot because of higher spinal cord lesion levels and the resulting arm dysfunction. In Twin Basketball, there are two shooting goals for each team, one is an ordinary basket (3.05m height) and another is a lower basket with 1.20 m height on the free throw line. Goal and shooting area differs with players' level of the physical dysfunction.

Moving tracks of wheelchair propulsion was obtained using FLT (fractional linear transformation, or 2D-DLT) procedures for matches of wheelchair basketball and twin basketball. International matches (Japan vs Korea for wheelchair basketball, and Japan vs Canada for twin basketball) were videotaped with a fixed camera set at the highest point of the audience stand. Two-dimensional coordinate system was set with X and Y axes along the side line and the end line, respectively. Twenty points with already known coordinates on the court, such as the intersection point of an end line and a side line, were used for the reference points for FLT calculation. Standard errors for the estimation were X=0.253 m and Y=0.102 m. Middle point of the wheels of each player was digitized every 0.33 second (3 Hz). Tracks, distance covered, and running speed were obtained for each player.

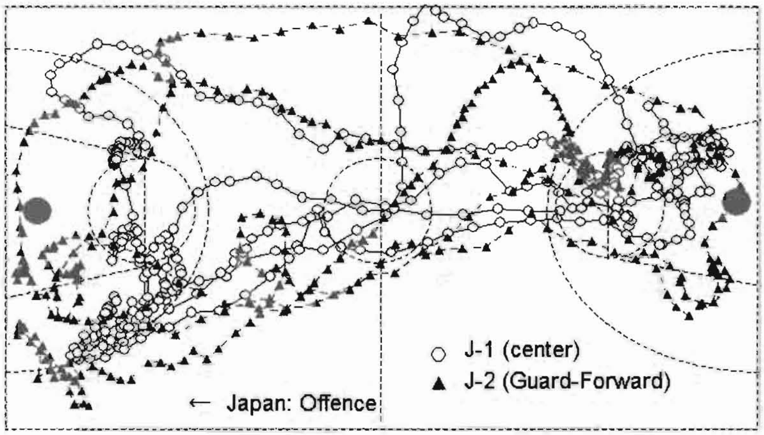

Figure 6 Moving tracks of two players in wheelchair basketball match

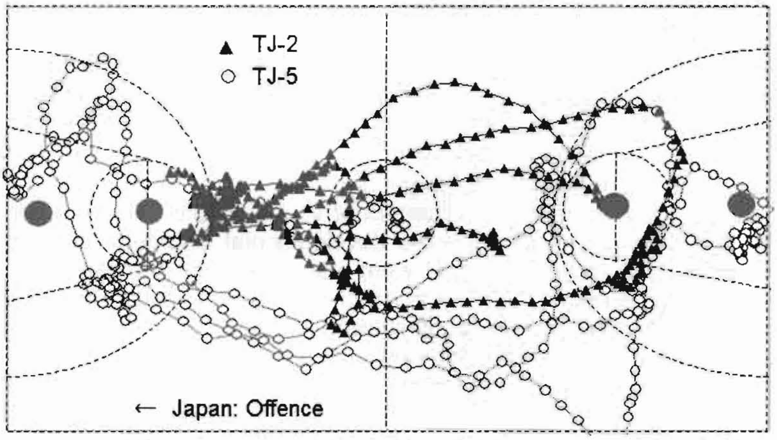

Figure 7 Moving tracks of two players in twin basketball match

Figure 6 and Figure 7 shows moving tracks of two players of Japan teams for two minutes during 1st quarter of the wheelchair basketball and twin basketball match, respectively. Distance covered and the maximum speed attained by each player was obtained for these periods and are shown in Table 1 for each player. The average distance covered in a minute was 94.6m for a wheelchair basketball and 80.6m for a twin basketball. In twin basketball, the distance covered and the maximum speed was smaller (85% and 72%) than those for wheelchair basketball, respectively. From these data we can find out the physical ability of the individual players in actual games. These data are also useful for match analysis and planning game strategies.

Table1 Distance covered and the maximum speed of each player for a wheelchair basketball and a twin basketball.

Wheelchair Basketball			Twin Basketball		
Player	distance (m/min)	max speed (m/s)	Player	distance (m/min)	max speed (m/s)
JAPAN			*JAPAN*		
J-1	99.3	4.30	TJ-1	84.4	3.38
J-2	100.8	4.03	TJ-2	71.9	2.30
J-3	112.9	5.25	TJ-3	85.0	2.92
J-4	78.4	4.66	TJ-4	73.8	3.38
J-5	101.3	4.71	TJ-5	90.5	3.85
average	**98.5**	**4.59**	**average**	**81.1**	**3.17**
KOREA			*CANADA*		
K-1	89.1	4.51	TC-1	70.5	2.87
K-2	94.1	5.23	TC-2	93.2	4.02
K-3	91.4	4.48	TC-3	89.2	3.85
K-4	85.0	4.12	TC-4	71.8	3.12
K-5	93.5	4.64	TC-5	75.8	3.30
average	**90.6**	**4.59**	**average**	**80.1**	**3.43**
Overall					
average	**94.6**	**4.59**	**average**	**80.6**	**3.30**
SD	**9.6**	**0.41**	**SD**	**8.8**	**0.53**

Development of Throwing Motion of Children with Learning Disorder: In recent years, several sport events for people with mental disorders have been included in Paralympic Games. Scientific support would be expected not only for physically disabled persons but also for intellectually retarded or mentally deranged persons.

In order to identify the movement development of young people with Asperger's syndrome (AS, or childhood autism, one of pervasive developmental disorders), throwing motion of fifteen AS children (7 to 15 years of age) were videotaped and compared with those from control group. The ball speed of the 9 years AS children was no better than the average ball speed of 7 year olds control. The AS group showed little improvement with increasing age in the speed of balls and wrists. Their throwing pattern was more like younger ages.Unique throwing patterns identified from the analysis included a lack of synchrony between step-in movement and ball release, and inconsistent sequences of peak velocities in the different body parts that should be chained from the shoulders to the wrists (Figure 8). However, after instruction and practice over one year, a clumsy girl in gross and fine motor coordination showed improvement both in throwing speed and throwing style.

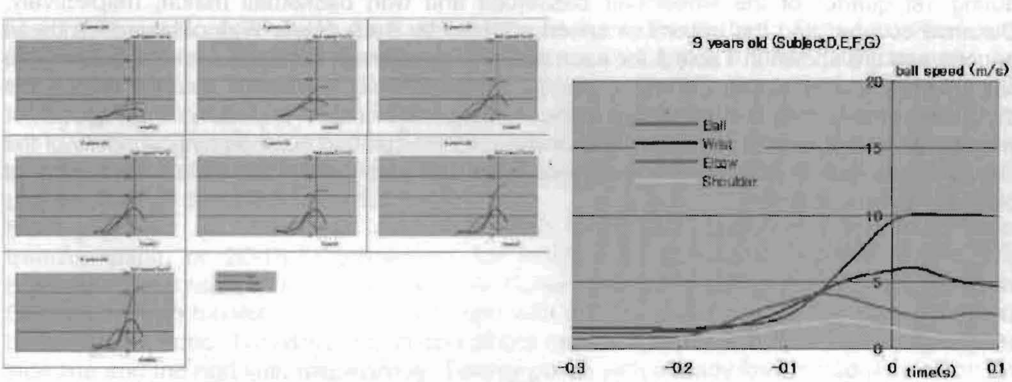

Figure 8 Velocity changes for each body part during throwing motions. (Left) for general population of 3 to 9 years old. (Right) for AS children of 9 years old.

Biomechanics of Adapted Physical Activity in the Future: Big and dramatic new world records have often been established in the Paralympic Games. Rapid advancement of performance levels in the sports for the disabled is partly due to improvement and development of new equipments, such as special racing wheelchairs and sit-skis. In a sense, most sports for the disabled are still in immature stage as competitive sports.
However, the Olympic sports and the Paralympic sports are not necessarily different genres. Adapted physical activity or adapted sports are not in a special category far from general physical and/or sports activities. In many cases, the same biomechanical analyses used in general sports activities can be applied to disability-based sports, as well.
Recently, many problems to be solved have been pointed out in the Paralympic Games. Some of them are in common with the case of the Olympics, such as doping, excessive commercialism, and so-called the North-South problem (the problem of disparity in economic levels between developed and developing countries). Another problem unique in the case of the Paralympics is the classification of the athletes.
The methodology and the knowledge of Biomechanics are expected to contribute to the development of competitive sports for the disabled especially in the following aspects in the future:
(1) to analyze certain sports skills and to advise athletes how to improve their skill levels
(2) to develop and amend sports equipment and apparatus based on the motion analysis
(3) to support competitors in training to improve their physical fitness levels
(4) to advise and support for the functional classification of the athletes

However, the greater part of the people with physical disabilities participate in sport activities mainly for rehabilitation, rather than for competitive interests. In Japan, about 70 % of physically disabled persons are of advanced years (over 60 years old). It is needless to mention that we, as biomechanists, must include this aspect while supporting Adapted Physical Activity.