A COMPARISON OF RACE PARAMETERS IN ICELANDIC SWIMMERS WITH AND WITHOUT INTELLECTUAL DISABILITIES

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Abstract

A COMPARISON OF RACE PARAMETERS IN ICELANDIC SWIMMERS
WITH AND WITHOUT INTELLECTUAL DISABILITIES

A systematic relationship between intellectual disability (ID) and reduced motor skill has not been shown. Athletes with ID are therefore no longer allowed to participate in the Paralympics Competition. To examine the swimming movement of ID athletes, video race analysis data has been collected. In short course races, swimmers with ID, although experienced, were more likely to use a deviating race speed pattern than other non-ID populations. This together with anecdotal evidence suggests that ID swimmers are not only poorer performers but also demonstrate more unstable performance. The purpose of this study was, therefore, to examine various aspects of race performance in ID athletes in a long course 200 m freestyle race and see how these changed within and between several races. This study included eight swimmers with ID and eight swimmers without Intellectual Disability (WID). All swimmers were videotaped from above water during 3 competitive races spread over 3 months. End result, clean swimming speed (CSS) (8x), turning and finishing speed, and stroke rate and length (8x) were measured and compared within and between races and between groups. Both groups had similar training backgrounds and competitive experiences, but the WID group performed relatively better as compared to population world records. ID swimmers showed a greater ($p<0.05$) between race variability in end result (3.11% +/- 0.89 vs. 1.75% +/-0.63) and in mid-pool swimming speed. There was however no significant difference between groups in the variation within the race in stroke length ($p = 0.17$) and no relationship between within race variation in stroke length and absolute swimming speed. Swimmers with ID, however, did exhibit a significantly greater within race fluctuation in stroke rate. This decreases slightly but unsystematically with decreased swimming speed in both groups. ID swimmers had relativity slower turns and showed more extreme values. On average ID swimmers did not start or finish slower in relation to overall race speed but extremely poor values were noted. In general ID swimmers showed less stable race patterns.

Útdráttur

Erfitt hefur verið að sýna fram á tengsl á milli skerts vitsmunaþroska og minnkaðrar hreyfifærni. Íþróttamenn með væga þroskahömlun hafa því ekki eins og mál standa í dag leyfi til að taka þátt í Ólympíumóti fatlaðra (Paralympics). Þessi rannsókn miðar að því að rannsaka hreyfifærni þroskahamlaðra (ÞH) sundmanna. Nákvæm keppnisgreining (race analysis) gerð með samstilltum videoupptökuvélum.

Í 25 m brautarlengd voru ÞH sundmenn líklegir til að nota frábrugðið mynstur á keppnishraða miðað við ófatlaða sundmenn ásamt því að sveiflur á lokatíma voru meiri. Þetta, ásamt öðrum óstaðfestum vísbendingum, bendir til að ÞH sundmenn séu ekki aðeins hægari heldur líka óstöðugri í keppnisframmistöðu sinni.

Tilgangur þessarar rannsóknar var að rannsaka ýmsar hliðar keppnisframmistöðu ÞH sundmann í 200 m skriðsundi sem fram fer í 50 m brautarlengd, og skoða hvernig þær breytast innan hverrar keppni svo og á milli þeirra. Sextán sundmenn tóku þátt í rannsókninni, 8 ÞH sundmenn og 8 sundmenn í samanburðarhóp. Allir sundmennirnir voru skoðaðir með videogreiningu á a.m.k þremur sundmótum á þriggja mánaða tímabili. Breytingar á lokatíma, sundhraða, takatíðni, takalengd, snúningstíma, byrjunartíma og lokahraða voru skoðaðar innan hverrar keppni og á milli móta og bornar saman á milli hópanna.

Báðir hóparnir höfðu svipaðan æfinga- og keppnisbakgrunn, en samanburðarhópurinn var samt sem áður betri bæði í beinum samanburði og einnig í samanburði við heimsmetin í viðkomandi flokki. ÞH sundmennirnir höfðu meiri mun á milli hraðasta og hægasta lokatíma (3.11% +/- 0.89 vs. 1.75% +/-0.63) og einnig í sundhraða og í þessum breytum var samspil (interaction) á milli móta og hóps. Það var hins vegar ekki marktækur munur á milli hópanna innan hvers móts í breytileika á takalengd (p = 0.17) og engin tengsl á milli breytileika í takalengd og sundhraða. ÞH sundmenn höfðu samt marktækt meiri sveiflur í takatíðni innan hvers móts. ÞH sundmenn voru hlutfallslega lengur að snúa við, en sýndu ekki marktækt meiri sveiflur í snúningunum. Að meðaltali voru ÞH sundmenn hlutfallslega ekki lengur að byrja eða með verri lokahraða en samanburðarhópurinn en útlagar voru algengari í ÞH hópnum. Almennt séð voru ÞH sundmennirnir óstöðugri en samanburðarhópurinn í keppnisframmistöðu sinni.

Formáli

Leiðbeindur að þessu 30 eininga meistaraverkefni voru tveir. Prófessor Erlingur Jóhannsson við KHÍ var aðalleiðbeinandi minn og vil ég þakka honum fyrir þolinmæði og að vísa mér leiðina í gegnum frumskóg vísindalegra vinnubragða. Án hans hefði ekki mikið gerst í framvindu rannsóknarinnar og lærði ég mikið af leiðbeiningum hans. Annar leiðbeinandi var prófessor Daniel Daly við KUL (Katholic University of Leuven) í Belgíu. Rannsóknin var að stórum hluta byggð á fyrri rannsóknum prófessors Daly og sá hann að miklu leiti um faglegar leiðbeiningar í framvindu rannsóknarinnar og var óþreytandi við að leiðbeina mér í ýmsum tæknilegum útfærslum á verkefninu. Einnig yfirfór hann alla tölfræðivinnu í verkefninu.

Til að kanna áreiðanleika mælinganna skoðaði Tina Vanneste meistaranemi við KUL nokkrar af mælingunum og þakka ég henni kærlega. Sigurbjörn Árni Arngrímsson dósent, kom mér svo í gegnum erfiðustu hjallana í tölfræði og kann ég honum bestu þakkir fyrir. Íþróttasamband fatlaðra studdi mig mikið fjárhagslega og með fyrirgreiðslu á margan hátt í gagnasöfnuninni. Þetta hefði verið erfitt án þeirra aðstoðar.

Að lokum þakka ég fjölskyldu minni sem alltaf studdi mig og sýndi mér þolinmæði allan tímann.

Heimildar kerfið sem notað er í ritgerðina er American Journal of Physiology.

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Introduction

General

Many studies have been done on the importance of physical activity and active lifestyle both for the general public as well as people with some kind of disability (6; 10; 26). Further many more studies have been done on elite athletes and their performance, but relatively little work has taken place on elite athletes with disability. The present study deals with athletes with intellectual disability (ID) who work hard to achieve good results in their sport, just as any ambitious athlete does.

The ability to participate in sport in a comfortable and confident manner is important for most people, including persons with ID (6; 37). Many persons with ID take part in sporting activities on a recreational basis for social contact as well as to maintain and improve general health. In Iceland where this study took place there are over 20 sport clubs that offer specialized sport programs for persons with disabilities and there are over 500 registered participants in these clubs (4). It is likely that there are many more disabled athletes taking part in organized sport without being registered as disabled in a population specific club. Approximately half of the population who takes part in sport for disabled athletes in Iceland is individuals with ID (4).

Individuals with ID are characterized by cognitive limitations as well as functional limitations in such areas as daily living skills, social skills and communications (28). Often IQ tests (like Wechsler) are used in the beginning to determine if an individual can be classified as ID. If a person is two or more standard divisions from the mean (IQ≤70) then he/she is considered legally ID (29). In today's complex society, however, these individuals are looked at much more closely and a multidimensional profile of their strengths and weaknesses is usually determined. These dimensions are usually divided into five categories (28).

Intellectual ability

Adaptive behaviour

Participation in everyday life

Health (mental and physical)

Context (involves the interrelated conditions within which people live their everyday life)

Each dimension is scored and it is then determined if the individual can be considered to be intellectually disabled within the society (28).

Some studies, like that done in northern England in 2004, have shown that a sedentary lifestyle is more likely to be found with people with ID than otherwise healthy persons (20). This is mainly due to the complexity and speed of present-day society and persons with ID have difficulties coping with this (19). The available evidence base strongly supports a high need for the establishment of community based, easily accessible physical activity programs for all children and adolescents in today's modern society (26) but even more so for individuals with ID (23; 28).

However, most children with mild and moderate ID differ very little from otherwise healthy children in their outward physical characteristics. Although most children with ID display developmental motor delays, they are often more limited when it comes to attention and comprehension (10; 28).

Competitive sport for ID

Some individuals with ID like many other athletes choose to take part in a competitive sport program. Although physical activity might be considered to have a recreational character for some individuals, the purpose for many is clearly to win races and not only to participate. A variety of factors will then come into play when a person with ID strives to optimize his or her sport performance. (Like all other athletes) Physical fitness (training), use of correct techniques (knowledge), adapting optimal race strategies (experience), suitable nutrition and rest as well as an environment conducive to proper training are needed to achieve a maximal level of performance (30). When an athlete strives to maximize his or her potential, much work is needed, both mentally and physically (34). Effectively including persons with ID in sports competitions not only requires in-depth knowledge of their physical skill acquisition, physical fitness, social skill development and overall functioning, but also of their mutual relationships and the interaction of the cognitive and neuropsychological potential of these sportsmen (29). A

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complex and unsafe environment has been shown to be less productive than an environment in which people can fully comprehend and feel safe and comfortable (1).

For some years individuals with ID have taken part in internationally organized sport events (2). These events, like the Paralympics games organized by IPC and Global Games organized by International Sport Federation for Persons with Intellectual Disability INAS-FID as well as many regional and national championships, all have the same rules as those organized for able-bodied persons (2). These events, which can be very complex and stressful are set up and run to find out who is the best among this population of individuals and should not to be confused with the large sporting event called Special Olympics, where the greatest achievement is, without doubt, to take part.

Eligibility

An additional problem that presents itself when competition is involved is that of eligibility or minimal disability. What should those athletes who compete as ID have as a minimum in common? Who can and who cannot take part? And more importantly, what kind of testing is needed to determine this? Presently eligibility for participation in competition organized by the INAS-FID is evaluated on the following standards (2):

- Minimum age requirement for international competition as set by international sport governing body (2).
  - This simply means that the same age restrictions are set for ID athletes as in all other international sports and this can vary from sport to sport.

- Intellectual disability formally diagnosed in accordance with accepted standards endorsed by international authorities in this area.
  - The second criterion further incorporates three requirements. a) There must be significant impairment in intellectual functioning as indicated by a full scale score of 74 or lower on an internationally recognized and professionally administered IQ test. b) There should be significant limitations in adaptive behavior as expressed in conceptual, social and practical adaptive skills established through the use of standardized

measures that have been norm-referenced on the general population including people with disabilities. The Sport Information and Consequences Questionnaire, SIC-Q is the main source of information for showing how and in what way an athlete's intellectual disability affects sport. c) Finally ID must be evident during the developmental period, which is from conception to 18 years of age (2).

- Evidence of the effects of an athlete's intellectual disability in sport needs to be presented.
  - In two Paralympics Games, Atlanta 1996 and Sydney 2000, athletes with ID competed beside athletes with loco-motor disabilities and visual impairment (in the swimming classification S14). After the Sydney Games, however, the International Paralympics Committee (IPC) asked for a review of this point (4). The IPC classification code states that to be eligible for Paralympics sport, an athlete must have a diagnosed physical, sensorial or intellectual condition that causes a permanent, objective and measurable impairment that has a verifiable effect on sport performance (24). At present the IPC does not accept athletes into Paralympics because of lack of evidence for this statement, but they recognize that progress has been made in the right direction (3).

In practice, this means that INAS-FID is not a full member of IPC and athletes with ID can therefore not take part in the biggest events held for disabled athletes such as the Paralympics Games, and will most likely not do so until more studies have shown clearly that ID affects the ability to perform at elite level.

For over seven years the National Paralympics Committees (NPC) from all over the world has argued about the way in which this situation should be approached. In many ways this situation is not only affecting the athletes with ID, but also the physically disabled athletes and visually impaired athletes who wish to take part in the Paralympics and/or world championship competitions in many disability sports. These big sports

venues can only host fixed number of athletes which means that IPC must allocate certain number slots to each disability group beforehand. It is clear that the group including athletes with ID is one of the largest disability groups, and would therefore take up many slots in these sporting venues, which in turn means that there can be fewer athletes from the other disability groups taking part in these big venues. Some delegates from certain NPCs have said that athletes with ID should not be in IPC regardless of all research and statistics; while most NPCs point out that IPC is for all athletes who can't take part in mainstream sport competitions, and agrees that ID athletes should be in the IPC as soon as it has been clearly established that their disability affects their ability to perform in their sport. Further, most NPCs agrees that a better classification protocol needs to be established. It is therefore of great importance for these athletes that a study, like this and many more will be conducted as soon as possible.

Studies on high performance ID athletes

The work here is a continuation of the first steps taken in swimming with respect to dealing with the question "Is there a relationship between intellectual disability and physical peak performance" that is not linked to lack of training or intrinsic talent for sport. Previously a large scale project was set up at the Global Games, a multi sport world championship for persons with ID held at the same venue (basketball, football, swimming, table tennis and track and field) (40). Here a first round of general as well as sport specific testing was done. Results showed that in comparison to population without intellectual disability (WID) data, both male and female Global Games participants scored better for flexibility and upper body muscle endurance, but had similar or lower values for running speed, speed of limb movement and strength measures compared to age-matched physical education students. Male athletes with ID scored better for running speed and flexibility and poorer for strength. Female athletes with ID were not different from able-bodied individuals for flexibility, running speed and upper body muscle endurance, but scored less well for strength measures (40). Athletes with ID also had poorer cardio-respiratory endurance capacity compared to sportive peers without ID (40). Within this group of athletes, swimmers were younger, more flexible, had better cardiovascular fitness in a running test but scored lowest in explosive leg strength.

To study swimming movement in more details, video race analysis data was collected on 89 elite male and 81 elite female swimmers with (ID) at the Global Games 2004 (13; 40; 43). Similar study was done at the Paralympics Games in Sydney 2000 (16) and more recently at the world championship in swimming for ID in Belgium 2007 (Article in review). These studies have mainly shown that the ID swimmers have similar race pattern as WID elite swimmers competing both at local sport meets as well as in major swimming meets like the Olympics, in 100 m freestyle race. Their swimming speed, stroke rate and stroke length changes in similar ways for both groups (13). On the other hand, all variables were of less amplitude, swimming speed was slower, stroke length was shorter and stroke rate was slower for ID swimmers despite similar physical characteristic of both groups (13; 40). The likelihood of something going totally wrong, (outliers) like totally missing a turn or being disqualified were also much higher in the ID group and the coefficient variant in between race performance (CV) is much higher in the ID groups (13).

A small study to examine the training behavior of top ID swimmers was done on 30 swimmers with ID from four different countries competing at BSE British Open swimming championship for disabled in the year 2006 (unpublished data.) The result from this study showed two main points, first that swimmers with ID who trained most (about 45 km/week) performed best at the meet, and indeed one male swimmer set a new world record in 400 m freestyle, and secondly that all ID swimmers from all the countries that took part in the investigation did relatively little land training, or on average about three hours a week in total including activities in their free time as well as school sport.

Presently, however, studies have been limited to in-depth investigations on ID swimmers at one single meet, and few follow-up studies have been done on ID swimmers. Recently, however, a follow-up study was done on swimmers with ID during repeated races of 200 m freestyle in a 25 m pool (short course). This study indicated that ID swimmers showed a greater between race variability than the control group in end result and mid-pool swimming speed. They also showed a greater variation in the relationship between change in stroke rate and change in swimming speed. ID swimmers had not only a shorter stroke length but also a lower stroke rate. ID swimmers turned slower and were

generally poorer and more unstable in the turns. They had more problems with the tumble turn than with pushing off from the wall. On the average, however, ID swimmers did not start or finish slower compared to the end result but extremely poor values were noted in this group, which were not seen in WID swimmers (42).

Elite performance

By looking at competition histories of both ID and WID athletes, anecdotal evidence suggests that ID swimmers are not only poorer performers but also show a much more unstable performance within and between races. They have less sense of race pace as suggested by previous findings, have slower reaction time (starting) and are more likely to perform complex tasks, like turning, incorrectly. They are not able to perform optimally at the critical moment. None of this, however, has been substantiated.

One study was done on young cyclists (15 year old) with ID and a control group of similar background. The result showed that the ID group scored significantly lower than their able body peers in post exercise blood-lactate and maximal power on a Wingate Anaerobic test. Their performance was also significantly more variable in repeated tests. That is, the ID group had much higher coefficient variance (CV) (9). The author suggested that the ID boys had fewer fast twitch muscle fibers but he also pointed out that there are no available data (in the year 2002) on muscle fiber profile of persons with ID.

People with mild ID (IQ=55-76) have also been found to be significantly more effected by interference during performance of a dual task (32). This could indicate that swimmers as well as other athletes with ID have poorer motor control when their stress level and other interfering factors might come into play. This again can lead to less stable performance, for example in starting, turning and swimming speed.

Many other authors have concluded that expertise in sport can be evaluated based on the stability of performance among other factors (7; 25; 36). The more stability in the performance the more advanced is the athlete (25). Stability in end result defines elite performance, but not necessarily when human motions are looked upon in close detail. Expert athletes seem to have the ability to compensate for small variations in their movement to maximize their end result with great stability (7). By looking at results from over 200 swimmers at national level without intellectual disability (WID) who did

repeated races with three weeks interval, it was shown that the mean difference between the end-result in the two races was 1.4% and on average faster swimmers had significantly less difference than the slower swimmers (38).

Similar results can be found in data available on www.swim.ee from Rein Haljand (22). He has carried out race analysis at numerous European championships in swimming both for senior and junior. All swimmers at this level show great stability in repeated measures, not only at end result, but also at how the race was performed. Stroke rate, stroke length and turning time variables are all stable for elite swimmers on international level.

Relationship between stroke variables

Several studies on elite WID freestyle swimmers have been done on the relationship between clean swimming speed, stroke length, and stroke rate. Most studies agree that differences in stroke length have a greater influence on swimming speed than differences in stroke rate between two swimmers (5; 8; 11; 12; 27). However swimmers will try to manipulate their stroke rate to cause short term changes in swimming speed. Similar results have been reported in elite freestyle swimmers with a locomotors disability (16; 35).

However, swimmers with disabilities have usually demonstrated more diverse combinations of stroke length and rate at a given swimming speed than did their WID colleagues (13). The relationship between intermediate swimming speed at various points in the race and overall race performance has also been examined. In addition, within race speed changes related to stroke length and stroke rate changes have been studied. In 200 m freestyle races speed in the second half of the race has the best correlation to overall performance (31), but in general, both swimming speed and stroke length decreased as the race progressed while the stroke rate was more fluctuating and often picked up at the end of race (5).

Turning in swimming

Turns are one of the more complex skills in swimming. Even though tumble turns are done repeatedly in practice and in races, every turn needs to be judged and performed a

little differently each time. The fact that a good swimmer travels over two meters in each stroke means, and that the swimming turns need to be performed at a distance from the wall that depends on the swimmer's size and swimming speed makes it very complex task. This requires the swimmer to make many decisions based on many variables every time he or she performs a tumble turn (39). In swimming literature, turning begins 5 m before the swimmers reach the wall. It is at this point that the swimmers start to line themselves up to make the actual tumble turn, and this can in fact reduce the swimming speed if not performed correctly. After that the push off phase takes over, where many good swimmers easily travel between 10 and 15 meters under water before they start to swim again. Usually the first 10 m are used as a reference point to determine the end of the turn (22). This means that in a 200 m race in a 50 m pool (3 turns) 45 m (or 22.5%) of the total race distance is turning. The fact that elite European swimmers spend on average 21.65% of their time in turning in 200 m freestyle in 50 m pool (22) shows that turning is relativity faster than other section of the race. This is mainly for the high speed the swimmers can get when pushing of the wall. ID swimmers have been shown to spend relatively more time doing their turns than WID swimmers at least in 100 m races (13; 17; 18). Turning and specially pushing off is considered very important factor to perform well in competitive races (29). Further, elite WID swimmers have shown great stability in their turning performance, where between races changes are about 1.5% (22).

Summary of previous studies

In general we know that ID swimmers can reach similar or better fitness levels as that of university students of the same age and gender (40). The main difference in their fitness level is that they seem to have less maximal power and strength (9; 40). They seem to respond to training the same way as WID athletes (the best swimmers trained the best), but train a little bit less and are less fit in general than elite WID swimmers (13; 40).

All race patterns in the 100 m freestyle swimming race look the same for ID as WID swimmers. The speed is highest in the beginning and the stroke length is longest early in the race, and both these variables decline steadily through the race. Stroke rate is highest in the beginning and declines towards the end of the race; although many swimmers try to increase it again to compensate for a shortening stroke length, and thus

maintain swimming speed. However all variables are smaller with the ID swimmers. They swim slower, they take shorter strokes and have slower stroke rates (13; 14; 15; 16).

Outliers happens more frequently with ID swimmers, extreme values are regularly reported in turn time, stroke rate and stroke length (13; 17).

There is also evidence that ID swimmers are less stable in their performance and more likely to deviate from their normal race pattern if they are interrupted or something unexpected happens (9; 32).

The aim of this study

Several studies have indicated that athletes with ID demonstrate instability in performance in several components of a competitive race. Until now only one preliminary study has attempted to quantify this instability over and within several complete swimming races. The purpose of this study was therefore to examine various aspects of race performance in ID athletes in an intermediate distance freestyle race (200 m = 150 s – 180 s) and see how these changed within and between several races. In addition, a control group of athletes without ID was also included who swam the same distances at the same competitions. For logistical reasons all swimmers were from the same small country. This eliminates some educational and social background questions which might otherwise arise. This also provided easier access to training background information as well as informed consent.

The following research questions will be investigated:

1. Is there a difference in physical capacity between experienced and trained ID and WID swimmers?
2. Do swimmers with ID show greater variance between meets in end race results than swimmers without ID in 200 m freestyle race?

If question two proves to be true:

3. Are greater end race result variations in ID swimmers due to greater variation in Clean Swimming Speed and is this due to variation in stroke rate and/or stroke length?
4. Or are end race result variations more due to variations in more complex tasks such as turning than to other parts of the race?

Method

Study population

Participants were five male and three female competitive swimmers with intellectual disability (ID) and four male and four female competitive swimmers without intellectual disability (WID). All volunteered to take part in this study. All swimmers or their guardians signed informed consent and the study was approved by The National Bioethics Committee. The swimmers with ID were all members of the Iceland national team for this population but not all freestyle specialists. Further all swimmers in the WID group were national team swimmers, either junior or senior, at the time. All ID swimmers had been classified as being eligible for participation in this category by the INAS-FID. The complete details of this procedure can be found at INAS-FID webpage http://www.inas-fid.org/pdf/INASIPCapplication.pdf (2).

Protocol

In this study all participants were asked to swim 3 or 4 * 200 m freestyle races in local or nationally organized competitions in 50 m pools (long course). The race was thus 4 pool lengths with a start, three turns and a finish. All the races took place in the same pool in a three month period from January to March 2007. In general all participants swam in the same pool on the same dates. All the race analysis was done during organized competition, either meets held especially for disabled or meets open for all swimmers. All swimming meets were official meets held under FINA and/or IPC rules and approved by the National Olympic Sports Association of Iceland (ISI). After each race, swimmers were asked to judge their effort on the Borge scale from 1 to 20 (33). Races scoring lower than 17 where discarded as being too slow and not used in the study.

The Borge scale has been used and validated over many years as a good tool for athletes to judge their own effort, both during practices as well as in races. The scale ranges from 1 – 20. Level 6 is total relaxation when awake; level 10 is light exercise, level 13 is hard, level 17 is very hard and level 20 maximal exertions.

In those cases that swimmers had four good swims the three fastest where chosen to be analyzed.

The swimmers were aware of the videotaping but did not receive any feedback on results until all three races were over. None of the participants who took part in the study received any guidelines prior to any race from the researcher, neither to swim the events at a certain race pace nor tactical information beforehand about each race.

Analysis of the 200m freestyle race

In general the same method was used as Daly *et al* (2005) in their study at the Global games 2004 and at the Paralympics games at 2000 in Sydney (13; 16).

Four 25 Hz digital video cameras (Sony Handy Cam 160) were placed perpendicular to the swimming direction, approximately 4-6 m away from and 3-m above the edge of the pool. Two cameras were placed 7.5 m from the turn ends (to cover the 5 m, 10 m, 40 m and 45 m), one camera 15 m from the start and one at the 25 meter mark (mid pool) (Figure 1). These reference lines have long been used by scientists to perform race analysis in swimming (14). At least 3 stroke cycles should be visible for all swimmers on cameras 1, 3 and 4. This is a new pool and has recently been approved by the Icelandic Swimming Association (SSI) and FINA as a legal pool, which in turn means that all (reference) markings on the pool deck needed for this study were accurate.

Start /Fin.	5 m	10 m	15 m	25 m		40 m	45 m
ⵍ							
ⵍ							
ⵍ							
ⵍ							
ⵍ							
ⵍ							
ⵍ							
ⵍ							

Figure 1: Overview of the setup in 50 m pool with camera placement.

Cam1   Cam2   Cam3   Cam4
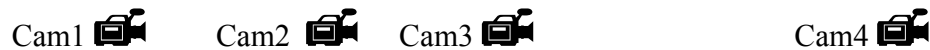
It was essential for camera synchronization that the start signal itself be recorded on the sound track of all cameras. It was also helpful if the starting light was visible in the cameras. The delay of the sound traveling to the cameras was calculated and taken into account when processing of data began (max 35 m from start end to camera 4). This sound track also included the race announcer's voice so that there was a double check of which race was in view. An electronic copy of all competition results was available from the server of the timing equipment after each swimming meet.

A commercial software program (Adobe Premiere 1.5) was used to help analyze the video pictures. First the video footage, including sound track, was captured directly into the computer for the entire race duration. Using the captured pictures the following frame codes were registered (manually) for every lap of the race:

- The moment the middle of the swimmers head reached the 15 m mark following the start or 10 m after each push off.

- The beginning and end of 3 arm strokes approaching the mid-pool line.

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- The moment the middle of the swimmers head passed the 25 m mark in the middle of the pool.

- The beginning and end of 3-4 arm strokes approaching the turn.

- The moment the middle of the swimmers head reached the mark 5 m before a turn or finish.

In addition the first video frame with start signal was registered from the captured tapes from all cameras.

An arm stroke cycle in freestyle is the time from one hand entry in the water until the following entry of the same hand. Two distance reference lines were visible in each camera view. Lines were visualized using markers on the plastic floating lines separating each competition pool lane and by drawing a line over the screen of the computer, with Adobe Premiere software.

Frame count recording was carried out by experienced persons. Double analysis of a race showed maximum errors of one frame count, 0.04 s, for any race section time or stroke count between and within analysis personnel. Minimum number of whole strokes recorded was 3 (minimum 80 frames) and section distance lasted at least 4 s (minimum 100 frames). All frame counts were entered into the Excel program and the race was divided in to 8 sections free of turns and starts.

Section1	Section2	Section3	Section4	Section5	Section6	Section7	Section8
10-25 m	25-45 m	60-75 m	75-95 m	110-125 m	125-145 m	160-175 m	175-195 m

Clean Swimming Speed (CSS), Stroke Rate (SR) and Stroke Length (SL) were calculated in all 8 sections of the race. Three 15 m Turn Times were also calculated from the point of 5 m before turn to 10 m after turn. In addition using the split or interval wall contact times, a turn time could be split into turn-in (5 m) and turn-out (10 m).
CSS is calculated by using the distance traveled and divide it by the time it to took to swim it. The Stroke Rate (SR) or frequency is the number of arm movement cycles/minute. Three whole arm cycles were timed (t= time in seconds) and then the SR was calculated by

$$SR = \left(\frac{60*3}{t}\right) \qquad \text{(Formula 1)}$$

When stroke rate and swimming speed are known one can determine the distance covered per stroke cycle (Stroke Length=SL).

$$SL = \frac{CSS}{SR} \qquad \text{(Formula 2)}$$

The Finish Time is the time of the final 5 m of the race. Several additional accuracy checks were built into the digitizing system. Total race times were estimated from the sum of all calculated race-segment times (including starting, turning and finishing) and compared to the actual race times obtained from the official timing system. This means that the measurement error maximal is around 0.5%.

$$(1\ frame) \div 2) \div 100\ (minimum\ frames\ in\ each\ interval) \qquad \text{(Formula 3)}$$

All videotaping where saved directly onto a computer but a back up was saved on a tape. This method saved 33% time. Without direct capture to computer, the analysis of one race with 8 swimmers took up to three hours.

Quantifying Race Speed and Stroking Patterns

Race patterns were described as the percentage changes in speed between adjacent race segments within a single race. This was also done for stroke rate and stroke length. Several other indexes were also calculated with the data to allow comparison between groups. Turn index was calculated as percentage of total race time, both as total turn time as well as single turn time. A Turn-in index and Turn-out index is the turn-in or turn-out speed/entire turn speed. Turn in-out index is turn-in/turn-out. Start index and Finish index are start and finish speed divided by the total race time.

Level of Competitiveness

To define level of competitiveness or performance, swimming times were given a score, using the method often used in swimming meets to compare results in different events and different gender. This method has also been used by Daly *et al* in several research papers on Paralympics swimmers (15). The method uses the following formula:

$$points = (\frac{World\ record\ (s)*10}{time\ (s)})\text{^}3 \qquad \text{(Formula 4)}$$

World record in our case is based on gender and class.

This same formula is used in the software that was available from KUL (Catholic University of Leuven) except instead of the world record they use average performance of 550 European swimmers, and correlate for different physical characteristics of each swimmer. This method is not as widely used because physical characteristics of swimmers are not always available.

General physical fitness measurements

All participants took part in swim-specific dry land physical fitness testing. Seventeen body structure measurements (appendix A) were taken, ten flexibility measurements were done and nine static strength measurements were carried out. Age, gender, and swimming stroke were related to norm scales based on 550 European level competitors to evaluate the general fitness level. Software was available from KUL (Catholic University of Leuven) to convert the individual raw data to percentile index scores corrected for age and body and limb size and length. These indexes have been shown to be related to swimming speed (41). These scores were again used to calculate the swimming performance level of the swimmers. That is, each swimmer was compared to a population of swimmers with similar body characteristic. All fitness measurements were done prior to the first race in January. The Researcher visited the training venue of the participants and conducted the measurements in the land training rooms of the respective clubs or at a local gym for two of the ID swimmers. All the measurements were finished the location, except for the flexibility measurements, in which case the swimmers were videotaped and flexibility measures were made afterwards using commercial software KINE view 2.1.

The use of this method allows the researcher to compare the performance of two swimmers in more detail than otherwise is possible. The software correlates for different body characteristic, strength and flexibility, before it gives individuals performance score.

Flexibility measurements

All flexibility measurements were done with KINE view software. Participants were videotaped doing the excersises and later analysed in the computer.

In the ankle flexion measurement, swimmer sits upright on the table with the legs fully extended, feet together and ankles maximally (dorsi) flexed. Reference points are drawn on both legs in the middle of the bony projection: of the outside of the ankle (medial malleolus) and of the lower outside of the knee (head of fibula) (table 1a).

In the ankle extension measurements swimmers sits in the same position as ankle flexion, the swimmer extends the ankles (plantar flexion) maximally. (Reference points on the medial malleolus must be adjusted for movement of the skin) (table 1b).

In the Ankle supination measurements the swimmer is sitting upright on a table, legs extended and heels on the table. The ankles are flexed in a position allowing maximum supination (foot soles pushed toward each other) (table 1c).

In the Ankle outward rotation measurements the swimmer is sitting, feet together, knees and ankles at 90°. With the knees held together by an assistant, the swimmer rotates the feet outward on the heels as far as possible and sets the feet flat (in one movement). No further adjustment is allowed (table 1d).
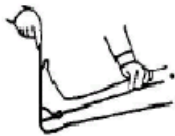
In the Hip outward rotation measurements the swimmer is standing, feet together, leaning against the wall with his outstretched arms. In one motion, he sets his weight on his heels and rotates his feet outward as far as possible, setting his weight back on his feet. The knees remain extended at all times. No further adjustment is allowed (table 1e).
In the Hip inward rotation measurements the swimmer is standing in the same manner as in hip outward rotation. In one motion, he sets his weight on the balls of the feet and rotates his heels outward as far as possible, setting his weight back on his feet. The knees remain extended at all times. No further adjustment is allowed (table 1f)

In the Shoulder abduction measurements the swimmer lies on his chest on a table. The throat is just touching the edge of the table. The arms are extended out to the side (precisely 90° to the trunk) and lifted as high as possible with the palms facing downward (table 1g)

Table 1. Measurement method in flexibility measurements.

Measurement	Description	Illustration
Ankle flexion	The angle between the foot sole and the lower leg is measured for both legs.	a
Ankle extension	A line is taken along the edge of the foot sole from the small toe to a point just before the heel begins for both legs.	b
Ankle supination	The goniometer is placed flat against the soles of the feet at the deepest point, while being held in a 90° angle to the foot.	c
Ankle-outward rotation	The goniometer is placed flat against the inside edge of the feet.	d
Hip-outward rotation	The goniometer is placed flat against the inside edge of the feet.	e
Hip-inward rotation	The goniometer is placed flat against the inside edge of the feet.	f
Shoulder adduction.	The goniometer is placed flat against the inside edge of the feet.	g

Strength measurements

The strength measurements were all done on location using: Calibrated spring scale with large readout and a hand that remains in place after the measurement (max 100 kg - 0.2 kg accurate), hand dynamometer, calibrated bathroom scale.

In the pull-push measurements swimmer sits on a chair with the pelvis stabilized by an assistant. One arm is held horizontal to the shoulder with the elbow at 90°. The forearm is set with the strap placed against the elbow bent. The free arm is completely extended to the side at shoulder level and a support is grasped (table 2a).

In the push (triceps) measurements the swimmer stands upright with the back against the wall. He grasps the hand grip, so that the angle between the upper and lower arms is 90°. The shoulder and elbow are stabilized and controlled by an assistant, who also checks the horizontal position of the forearm and the extended position of the wrist (table 2b).

In the upward lift (latissimus - triceps) measurements the swimmer lies on his back on the table. In one hand he takes the handgrip with the thumb against the thigh. He stabilizes himself sufficiently with his other arm (table 2c).

In the Squeezing (pectoralis) measurements the swimmer is standing erect holding the scale vertically at chest level (table 2d).

In the hand grip (hand and fore-arm flexors) the swimmer is standing with a dynamometer in his hand hanging at his side. The dynamometer is adjusted so that it rests in the palm between the base of the thumb and the fold between the second and third row of phalanxes (table 2e).

Table 2. Measurement methods in strength measurements.

Measurement	Description	Illustration	
Pull-push (latissimus-pectoralis)	Push as hard down as possible, with shoulders level at all time. Repeated for both arms.		a
Push (Triceps)	Push as hard down as possible with elbows remaining at the side all time. Repeated for both arms.		b
Upward-lift (latissimus triceps)	Push as hard down as possible with hips level at all time. Repeated for both arms.		c
Squeezing (pectoralis)	Keep the elbow level all the time.		d
Hand grip (hand and fore-arm flexors)	Keep the arm straight all the time. Repeat for both arms		e

Questionnaire

All participants filled in a training background questionnaire with the aid of their coach. The questions concerned years of training, quantity of training last year, dry land training, facility access, and financial assistance (Appendix B). Participants were asked to evaluate all their dry-land training aspects, not only what they do with their swimming group, but also if they were doing something else, like in school or in other sport, organized or not. This is the same questionnaire that has been used in several occasions (13; 40).

IQ values

ID swimmers who wish to participate on international swimming meets must submit their IQ-test papers to the governing bodies of INAS-FID and IPC. Those IQ values were also collected in this investigation for later comparisons. These values were however only available for ID swimmers so they were not used much in the comparison of the two groups.

Statistical procedure

Several statistical steps were taken to fully examine the data collected. To describe the participants, means, standard deviations, and minimum and maximum values were determined as well as the coefficient of variation (CV = *SD/M*). Differences between the groups were examined for race segments speed, stroking variables as well as body characteristics and physical test results using student t-tests.

For the further analysis the results were ordered from best (day 1) to slowest (day 3) end race result. Cluster analysis was conducted (Centroid) to determine if there were any general groupings of swimmers with similar race patterns or to isolate swimmers with unusual patterns. Input was the percentage changes within the race in adjacent race segment speeds. Within-race changes in race-section swimming speed, stroke length, and stroke rate were evaluated using repeated measures ANOVA ($p < 0.05$) for race segment with interaction for class (group). When sphericity was not assumed, Greenhouse- Geisser correction was used to determine the statistical significance.

Three levels of correlation analysis were potentially applied. In an across-race analysis the total race time was correlated with a race segment time. In a within-race analysis, a total race time was correlated to a change in speed within the race, (e.g. a percentage speed change between adjacent race sections). In a between-race analysis a percentage change between two races (heats to finals) e.g. in total race time, was correlated to the percentage change in a segment time or stroke length. Within race changes in stroke rate or length were also related to within-race changes in speed. Correlations were calculated using the entire group of swimmers available and in grouping swimmers in a category (able bodied, visual, intellectual, loco-motor, able bodied youth). To the extent that these changes are related to race success, they can also be related to the body characteristics of the swimmer.

For correlation analysis, swimming times were converted to speed (distance/swimming time) or to a point score based on the event world record (41). In this way, a better performance was always reflected by a higher value. In addition, the point score for competitiveness provided a more normal distribution of swimming times.

To analyse the correlation within each race, changes in speed, stroke rate, and stroke length, were calculated between each segment. Spearman's correlations were then used to estimate correlation between speed and stroke rate and speed and stroke length, for each race.

Results

Participants

Sixteen individuals voluntarily took part in this study, eight swimmers with ID (three women and five men) and eight swimmers WID (four women and four men). The swimmers with ID had all passed the INAS-FID protocol (IQ-testing and completed the questionnaire) for eligibility for international participations in ID sport. They were also all members of the Icelandic national team for this population and with one exception were all freestyle specialists. Six WID swimmers were also part of the Icelandic national team and again with one exception all were freestyle specialists. As can be seen in Table 3, swimmers in both groups were of similar age, height and weight.

Table 3. Means, standard deviations and p-values for the main descriptive characteristics of the study population, for swimmers with- and without Intellectual Disability.

	ID (8)	WID (8)	statistical-value
Age (years)	18.9 (+/-3.7)	17.6 (+/-1.7)	Ns
Height (cm)	173.6 (+/-9.2)	174.3 (+/-15.6)	Ns
Weight (kg)	66.5 (+/-10.7)	71.1 (+/-10.4)	Ns
Body fat (%)	14.7 (+/-7.3)	13.7 (+/-6.5)	Ns
BMI	22.0 (+/-2.7)	23.4 (+/-1.3)	Ns
Training years	8.1 (+/-1.9)	8.8 (+/-3.2)	Ns
Hours in pool/week	13.1 (+/-1.9)	16.9 (+/-1.1)	*
Km/week	32 (+/-8.3)	49 (+/-2.5)	*
Best times (2006)	2:48.59 (+/-16.3)	2:07.38 (+/-4.9)	*
Best score (2006)	482 (+/-88)	638 (+/-38.1)	*
Total Races last year	85 (+/-8.1)	80 (+/-5.5)	Ns

*p<0.05 Best score is here calculated by using formula 4 (pages 23). World records are selected for each group and gender.

There was no statistical difference in body fat, BMI or in how many years the swimmers had trained or in their competitive experience.

WID swimmers were as expected faster than their colleagues with ID. When performance level is represented in a point score based in the group world record, WID swimmers also come out better ($p<0.05$). In short WID swimmers were both better in absolute, and relative terms. WID swimmers swim both more hours and more kilometres each week. Only ID swimmers who take full part in a WID program practiced twice a day. The results in table 1 show that WID swimmers swims about 2.9 km/h while ID swimmers do 2.4 km/h in the same period ($p<0.05$). This relates directly to the higher swimming velocity of the WID swimmers.

Most ID swimmers were in the same program as the WID swimmers and trained almost exclusively with the WID swimmers who also took part in this study. Only two swimmers with ID did not swim at all with WID clubs. All other ID swimmers took part in the same swimming sessions as their WID swimming peers, had the same coaches and the same facility. All swimmers, both ID and WID, had a short and long term training plan in progress and regularly had race simulations as part of their water sessions.

WID swimmers take part in approximately 14 swimming meets a year, some of which were spread over several days. They therefore swam between 80 and 100 actual competitive races each year (Table 3). The ID swimmers in WID clubs had, in some cases done more racing than the WID swimmers, as they took part in all club competitions for able bodied swimmers but also competed in 2 to 4 meets with the population national team.

When it came to accessibility to training facility, there was no difference in the groups. Both ID and WID group have are using the same facility in the water and on land when it came to strength and flexibility exercises.

None of the swimmers received any official financial support, but all swimmers had some support for training equipment and some travel costs were covered , either by SSÍ (Icelandic Swimming Association) or by IF (Icelandic Handicapped Sport Association).

When the participants land training habits were examined large differences did appear (Table 4). Dry land endurance included all activity on land that could be

categorized as endurance training for this population (running, biking, field games etc.). All swimming clubs in Iceland do some kind of endurance training on dry land each week, except the clubs exclusively for ID swimmers. Furthermore few of the ID swimmers in the WID swimming programs took part in the land endurance training.

Table 4. Land training habits and physical characteristics for swimmers with and without Intellectual Disability.

	ID (8)	WID (8)	statistical-value
Endurance (h/week)	0.5 (+/-1.1)	2.1 (+/-0.6)	*
Flexibility (h/week)	1.7 (+/-0.5)	1.8 (+/-0.3)	Ns
Strength (h/week)	1.3 (+/-1.1)	3.9 (+/-0.4)	*
Flexibility score (%)			
Ankle flexion	57.1 (+/-24.5)[a]	71.0 (+/-23.2)	NS
Ankle ext.	55.1 (+/-21.6)[a]	47.9 (+/-18.1)	NS
Ankle sup.	71.2 (+/-18.3)	55.4 (+/-17.1)	NS
Ankle outward rot.	38.3 (+/-13.1)	40.5 (+/-14.2)	NS
Hip-outward rot	37.5 (+/-11.6)	45.4 (+/-13.8)	NS
Hip-inward rot	42.5 (+/-13.7)	45.4 (+/-19.0)	NS
Shoulder ad.	47.5 (+/-11.4)[a]	40.4 (+/-12.5)	NS
Strength score (%)			
Latiss, pect. Push	41.1 (+/-11.9)[a]	21.9 (+/-18.6)	*
Triceps push	65.1 (+/-20.1)[a]	28.9 (+/-15.4)	*
Latismus push	61.4 (+/-17.3)[a]	40.3 (+/-21.5)	*
Pectoralis squeeze	62.5 (+/-11.1)	49.9 (+/-10.1)	*
Forearm	71.1 (+/-19.6)[a]	33.9 (+/-23.7)	*

*$p < 0.05$ a=average for left and right limb.

All score results in the table for flexibility and strength are score based on the body characteristic, age and gender from 550 WID swimmers in Europe (41).

There is a large and a statistical difference in the amount of strength and endurance exercises the groups do on land but very little difference on flexibility training (Table 4).

There is no statistical difference in any flexibility score between the groups, and they are in fact almost identical. Only three of these flexibility measurements (ankle extension, ankle supination, and shoulder abduction) have been shown to be important to performance in freestyle (41) and in all of these measurements the ID swimmers are actually slightly better although it is not statistically significant (Table 4). On the other hand there is a great difference between the strength measurements, and there is always a statistical difference between the groups. All of these strength measurements have been shown to be important to performance in freestyle swimming.

In a pilot study done on the same ID population plus 22 other top level ID swimmers from all over Europe, competing at BSE international disable swimming meet in Sheffield England 2006, similar results were found regarding land training habits of ID swimmers as can be seen on figure 2.
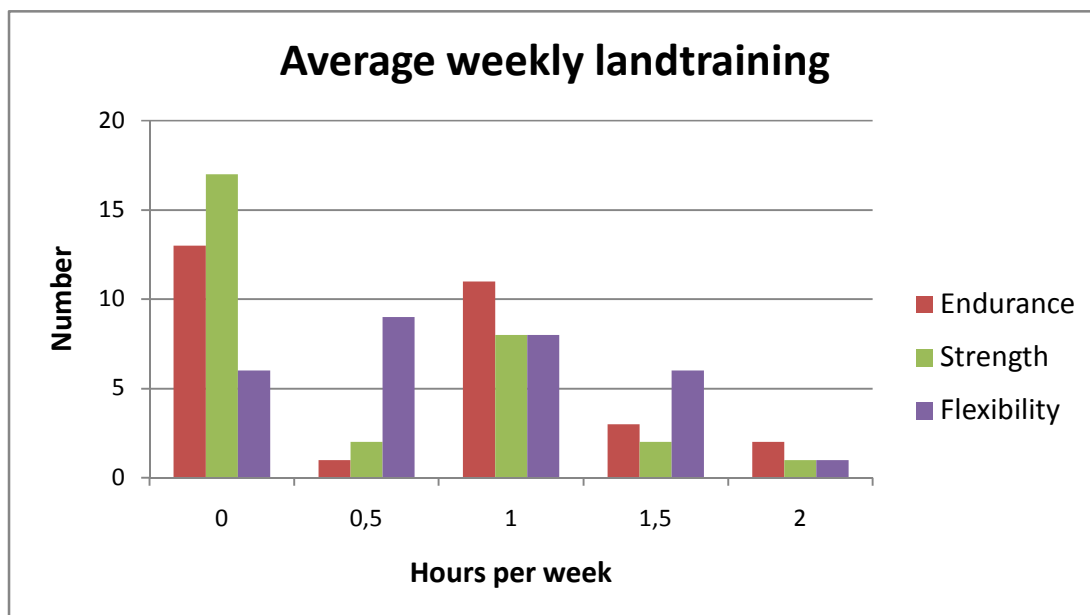

Figure 2. Land-training hours a week in total, (including school activity) of 30 ID swimmers competing on BSE 2006.

It is clear from table 2 and figure 2 that top ID swimmers train less than top WID swimmers, especially when it comes to strength training and endurance training on land.

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ID swimmers in this study are also weaker than the WID swimmers, but their flexibility is the same.

Figure 3 shows average score for all flexibility and strength measurements for both groups based on population of swimmers with similar body characteristics. It also shows actual swimming performance score for both groups based on the same population as before. So here both groups are compared to the same population of WID swimmers from Europe.
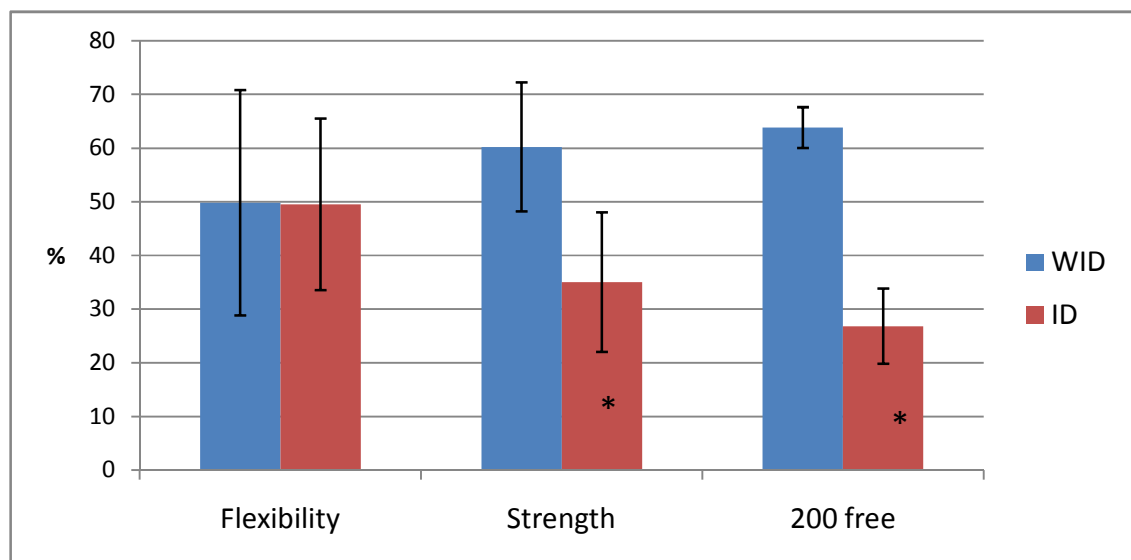
Figure 3. Average flexibility, strength and performance score based on the body characteristics, age and gender from 550 WID swimmers in Europe (41).
*p<0.05 between the groups.

On this European scale which uses 550 swimmers as control and 100% is what the best elite swimmers score, both the WID group and the ID group, are average or around 49.5% in flexibility. In strength the WID swimmers jumps up to 60% but the ID swimmers sink down to 35%. In actual swimming performance the WID swimmers rise even more to 62.5% and ID swimmers are only 27.7%. The difference on the two groups in strength is 71% but in actual swimming performance it is 125%.

End race results and Borge scale

Over the period of this investigation seven swimmers with ID improved their best performance in 200 m freestyle and one swimmer was less than 1,5 s away from his best time. The average improvement in relation to the personal record was 4.35 s (+/- 4.5 s) In the WID group five swimmers improved their best times and the other three all came within 1 second of their best times. The average improvement was 0.7 s (+/- 1.1 s) ID swimmers are always slower than the WID swimmers and that the ID group is more homogeneous (higher SDs) (Table 5)

The Borge scale was used originally to determine if all swimmers were sufficiently motivated in each race. It was clear that the ID group had little or no feeling for this scale and/or that they always gave their 100% best. On the other hand the Borge scale seems to reflect very well the effort the WID put into the race and their actual performance. The Trend-line through the data for the ID was $y=-1.216x+150.6$ ($R^2= 0.96$)

One of the criteria for accepting a swim into this study was that a score of 17 or above had to be reported on the Borge scale. This is very high, but 200 m swimming events are often considered as one of the hardest, mainly because, swimmers needs to use their aerobic and anaerobic capacity to maximum level (34). On eight occasions swimmers in WID group scored lower than that. In all cases their time was much slower than their most recent personal bests. Some admitted to not trying and in two cases they had been instructed by the coach to use a "tactical" race plan, to swim the first part of the race "slow" and then really push hard in the second part. All these swims were discarded. The ID swimmers always said they tried their absolute best and in very few cases did they admit to have had "something left in the tank."

The mean maximal change over the three races in ID swimmers was 3.11s +/-0.89 and 1.75s +/-0.63 in the WID group. Both of these changes were significant. There was also a statistically significant interaction between class and meet. That implies that the ID swimmers were less stable and less predictable on end race results over time. The difference between the groups lies in that the changes within ID group between races 1-2, 2-3 and 1-3 are all statistically significant but only changes from 1-3 in the WID group is significant.

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Table 5. Mean end race results (final time) and Borge scale for three 200 m freestyle races in swimmers with and without Intellectual Disability. Table also includes the mean difference in % between race 1-2; 1-3; and 2-3.

	ID (8)	WID (8)	Significance
Race 1 (min)	2:44.23 (+/-15.9)	2:06.76 (+/-8.10)	*
Race 2 (min)	2:46.55 (+/-16.14)	2:07.46 (+/-8.84)	*
Race 3 (min)	2:49.23 (+/-16.14)	2:09.01 (+/-9.33)	*
Borge scale1	19.9 (+/-0.3)	19.2 (+/-0.5)	*
Borge scale2	19.9 (+/-0.3)	18.3 (+/-0.6)	*
Borge scale3	19.9 (+/-0.3)	17,7 (+/-0.8)	*
Δ 1-2 (%)	1.42 (+/-0.86)	0.55 (+/-0.34)	*#
Δ 1-3 (%)	3.11 (+/-0.89)	1.75 (+/-0.63)	* #
Δ 2-3 (%)	1.67 (+/-0.75)	1.19 (+/-0.62)	Ns #

* $p < 0.05$ absolute difference between the groups.

\# $p < 0.05$ interaction between class and meet.

Clean swimming speed, stroke rate and stroke length

Mid-pool velocity is the swimming speed without influence of starts or turns. Again there is a statistically significant difference between the groups if we look at clean swimming speed (Table 6). WID swimmers were always faster. There was also a significant difference in clean swimming speed (CSS) between races in both groups but with interaction. Swimming speed is more stable between races in WID than in ID swimmers. CSS was actually measured 8 times within each race. The p-value for interaction of within race changes approaches significance $p = 0.078$. The interaction is mainly towards the end of the race, where ID swimmers tend to be more unstable in their speed. This means that ID swimmers show higher variations between races (Table 6) as well as within each race itself.

Table 6. Mean clean swimming speed (CSS), stroke rate and stroke length for three 200 m freestyle races in swimmers with and without Intellectual Disability.

|	ID (8)	WID (8)	Significance
CSS 1 (m/s)	1.21 (+/-0.12)	1.55 (+/-0.11)	* #
CSS 2 (m/s)	1.19 (+/-0.11)	1.54 (+/-0.10)	*#
CSS 3 (m/s)	1.17 (+/-0.11)	1.53 (+/-0.11)	*#
Stroke rate 1 (Hz)	40.0 (+/-3.21)	43.70 (+/-3.03)	
Stroke rate 2 (Hz)	40.15 (+/-3.50)	43.52 (+/-2.33)	
Stroke rate 3 (Hz)	38.15 (+/-2.51)	42.92 (+/-2.23)	
Stroke length 1 (m)	1.83 (+/-0.33)	2.14 (+/-0.21)	*
Stroke length 2 (m)	1.79 (+/-0.17)	2.14 (+/-0.20)	*
Stroke length 3 (m)	1.83 (+/-0.13)	2.15 (+/-0.22)	*

* $p<0.05$ absolute difference between the groups. # $p<0.05$ interaction between meet and class

Stroke rate was lower for ID swimmers, without reaching statistical significance but stroke length was significantly shorter for ID swimmers (Table 6). There was however no significant interaction for between race changes and group (stroke rate $p=0.537$; stroke length $p=0.775$) or for within race changes and group (stroke rate $p=0.761$ stroke length $p=0.099$). However, if we look at the mean individual coefficients of variation (CV) for stroke rate over all races they are twice as high in the ID group (5.09% +/-2.9 vs. 1.80% +/-0.87). Although we do not find statistically significant differences it nevertheless appears that stroke rate is much less stable within the race of ID swimmers if we look at CV for each group.

Again there is clear difference between the two groups when it comes to compare actual stroke length, but there is not a significant difference across the meets. Again the CV for stroke length for ID group is much higher than for the WID group (3.19% +/-1.09 vs. 0.99% +/-0.17).

If we only look at changes within each race between race segments we can further see that there is a difference in between the two groups (Figures 4a, 4b and 4c).

Figure 4a shows steady decline in stroke length for WID swimmers, with very little unexplained changes between the segments in their fastest race. ID swimmers also have a decline in their stroke length but it's not a smooth descent.
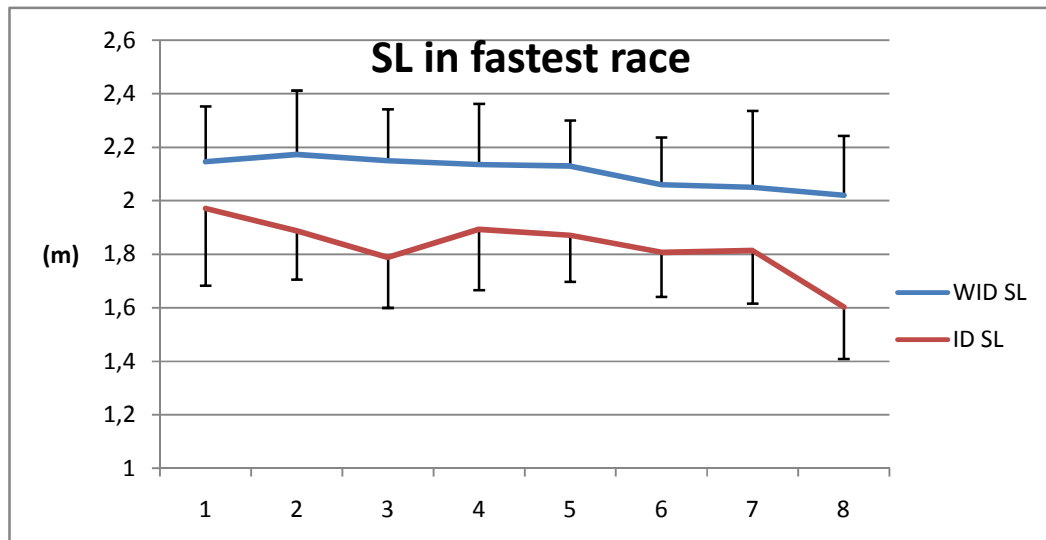
Figure 4a. Shows the average stroke length (SL) in each race segment in the fastest race for ID swimmers and WID swimmers.

Figure 4b shows how both group slow their stroke rate (SR) in the beginning, maintain it in the middle of race and then most swimmers will try to increase their stroke rate towards the end of the race to maintain swimming speed, when the stroke length becomes shorter because of fatigue.
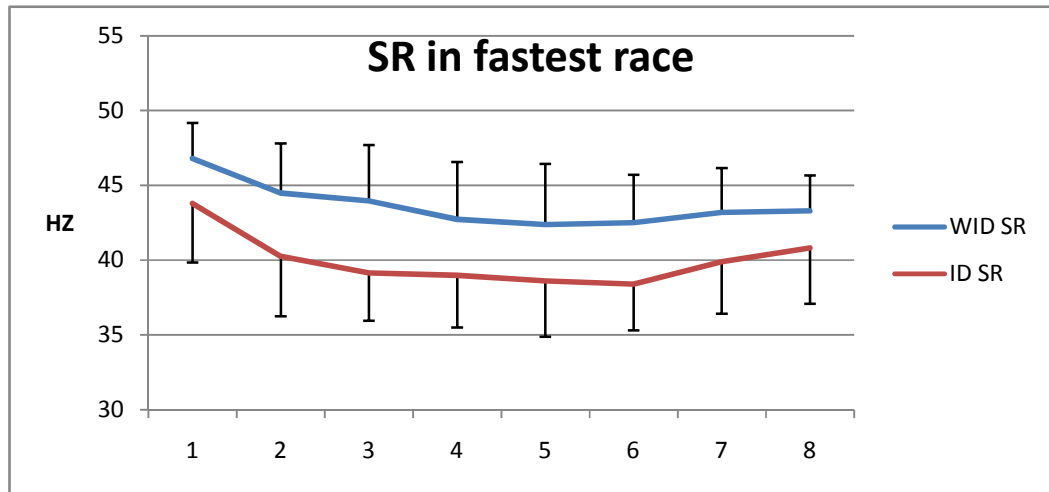
Figure 4b. Shows the average stroke rate (SR) in each race segment in the fastest race for ID swimmers and WID swimmers.

Figure 4c shows how the WID swimmers mainly decline in their clean swimming speed (CSS) as the race progress. They have a little rice in segment 7 which is directly after the last turn, when they start to swim the last lap. The pattern for the ID swimmers is much more unstable, like their stroke length pattern.
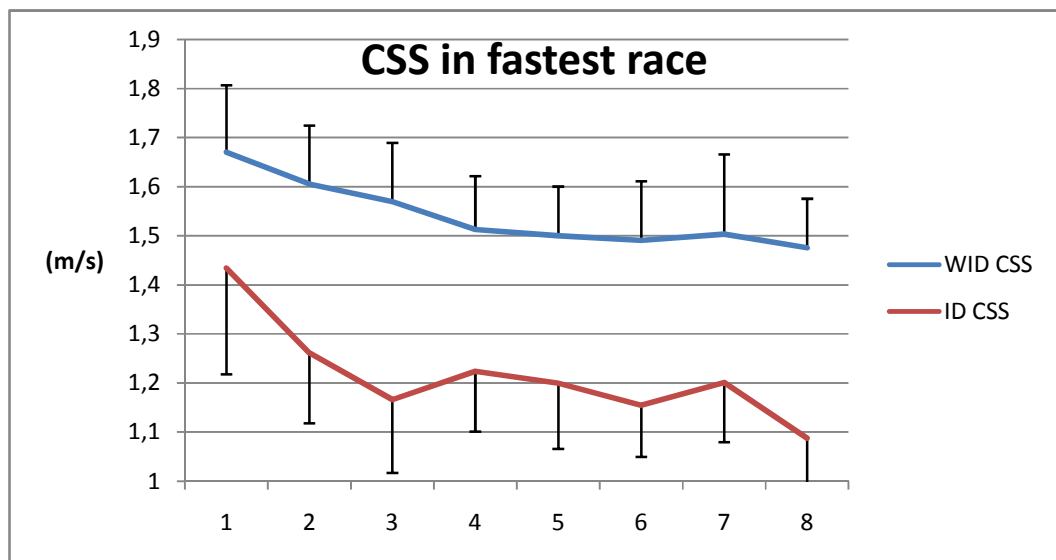
Figure 4c. Shows the average clean swimming speed (CSS) in each race segment in the fastest race for ID swimmers and WID swimmers.

Turning

As expected ID swimmers turned slower than WID swimmers (p<0.05) in absolute term and they also spent relatively more race time turning (Table 7).

Table 7. Mean turn time for all turns in all the races both in absolute and relative terms (percentages of total race time spend doing the turns) in swimmers with and without Intellectual Disability.

	ID (8)	WID (8)	significance
Turn time race1(s)	36.56 (+/-3.31)	27.78 (+/-1.09)	*
Turn time race 2 (s)	36.93 (+/-3.28)	28.03 (+/-1.41)	*
Turn time race 3 (s)	37.59 (+/-3.04)	28.35 (+/-1.30)	*
Relative turn time 1 (%)	22.23 (+/-0.10)	21.92 (+/-0.05)	*
Relative turn time 2 (%)	22.24 (+/-0.09)	21.97 (+/-0.05)	*
Relative turn time 3 (%)	22.23 (+/-0.10)	21.97 (+/-0.04)	*

*p<0.05

There is, however, no interaction between meet and group in turn time nor was there an interaction for within race turn changes and group. The ID swimmer did not fluctuate more than WID swimmers in their turning speed. If we however look at the average CV for each swimmer for all the meets we find that the ID swimmer have 4.93% +/-1.72 while CV for WID swimmers is 3.61% +/-1.12. It is clear that ID swimmer both turn slower in absolute terms and spend more race time turning (Table 7).

First turn in each race was statistically fastest for both group (p<0.05) but turn 2 and 3 had no statistical difference. Outliers appeared more frequently for WID swimmers towards the end of each race where ID swimmers showed outliers in the races

Starting and reaction time

As expected the ID swimmers were much slower in the first 15 m (start time) of the race and they had a longer reaction time as can be seen in Table 8.

Table 8. Mean starting time (time from 0 – 15 m line), mean start index (percentage of total race time spent in the first 15 m) and mean reaction time (time until feet's leaves the starting block) for swimmers with and without Intellectual Disability.

	ID (8)	WID (8)	significance
Start time race 1 (s)	9.43 (+/-0.74)	7.45 (+/-0.70)	*
Start time race 2 (s)	9.17 (+/-1.05)	7.45 (+/-0.68)	*
Start time race 3 (s)	9.45 (+/-1.10)	7.61 (+/-0.74)	*
Start index 1 (%)	5.74 (+/-0.31)	5.87 (+/-0.11)	Ns
Start index 2 (%)	5.51 (+/-0.32)	5.85 (+/-0,15)	Ns
Start index 3 (%)	5.58 (+/-0.36)	5.89 (+/-0.15)	Ns
Reaction time 1 (s)	0.95 (+/-0.06)	0.81 (+/-0.03)	*
Reaction time 2 (s)	0.91 (+/-0.13)	0.82 (+/-0.03)	*
Reaction time 3 (s)	0.95 (+/-0.06)	0.82 (+/-0.03)	*

*$p < 0.05$

Although there seems to be more fluctuation in the ID group there is no statistical difference in the variance between the meets (p=0.39) When the start time is taken as a percentage of total time we see that both groups spend similar percentage of their total race time in the first 15m of the race ID 5.91% +/-0.33 vs. 5.89%+/-0.15. There is no statistical difference between the groups but CV is twice as high for the ID group 5.53% +/- 1.10 vs. 2.72% +/-1.03. ID swimmers are slower off the block (reaction time) but statistically there is no difference in variance between the groups between the meets. Again the CV is higher in the ID group 4.1% +/- 0.9 vs. 1.2% +/-0.2.

Relative changes from fastest race to slowest race

If we only look at changes between the fastest race and the slowest it is clear that the two groups show a statistical difference in 4 out 6 variables as can be seen in figure 5. Average stroke rate, swim speed, turn time and start time are slower for all participants in both groups, but the average stroke length increases for some individuals in the slower race, which can explain this very little change in stroke length.
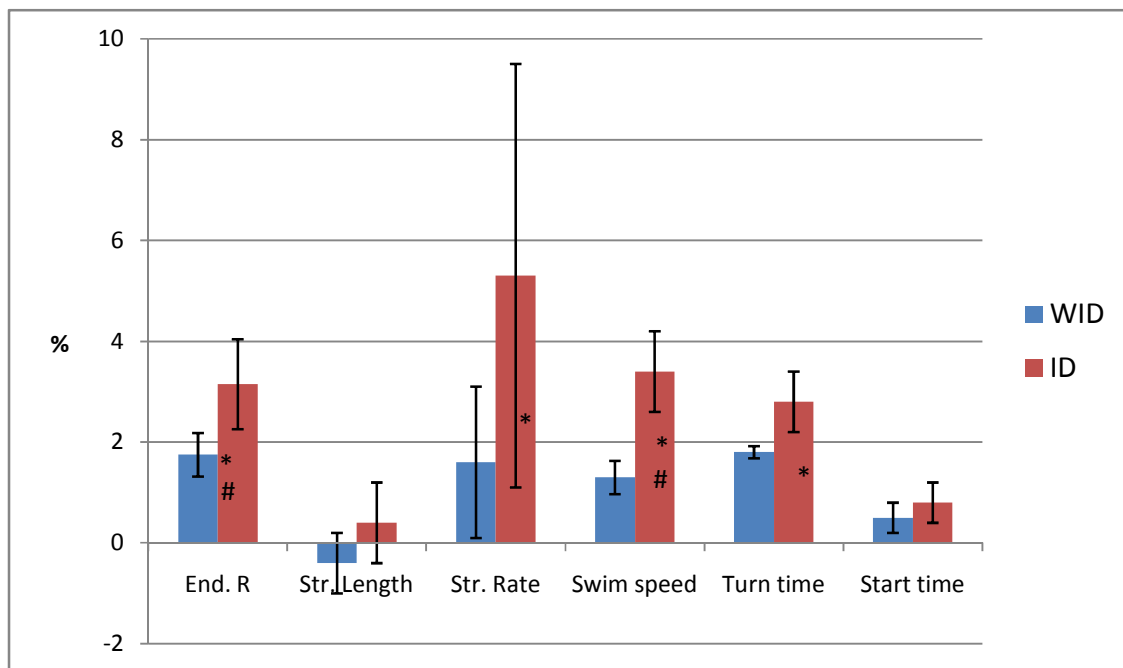
Figure 5. Shows the average difference in percentage between the fastest and slowest race for both ID and WID swimmers.

* $p < 0.05$ absolute difference between the groups

# $p < 0.05$ interaction between meet and class

Discussion

Participants

The participants in the ID group all meet the minimum requirements to take part in INAS-FID international swimming meets. This does however not mean that they have all the same or have similar IQ scores. Actually there is about a 20 points range in the IQ of the participants, although most swimmers in this group are close to the cut off limit INAS-FID sets for eligibility of athletes who can take part in international meets.

It can be seen from table 3 that participants in both groups are very similar in all body characteristics. They have the same cultural background, and practically same opportunities to participate in the sport of swimming. They are coached by the same coach most of the time or at least swim alongside each other and are following the same training program. The fact that ID swimmers swim fever hours a week than swimmers in the WID group can mainly be explained by the fact that they seldom do morning practices. This is the same result as was found in research done in Belgium on ID swimmers from Global Games 2006 (43). There is no single explanation for this, but no swimmers in the ID group in this study had a driving license and they are very dependent on their parents or guardians for transportations early in the morning when buses are not in service.

Another finding is that ID swimmers take much less part in land-training programs, both for strength and endurance but they spend similar time on flexibility. The results for dry land flexibility training indicate that all Icelandic swimming clubs do some stretching before entering the pool on the pool deck. This goes both for ID and WID clubs (table 4). ID clubs in Iceland do on the other hand not have special strength programs or land endurance program and ID swimmers in WID programs often do not take part in the strength training sessions.

This result is very similar to what was found in a study done on 30 swimmers with ID from 4 different countries competing at the BSE British Open Swimming Championship for Disabled in the year 2006 (unpublished data) (figure 2) and shows that this is not only a problem in Iceland, but it seems to normal for this population. Similar

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findings were reported from Versichel & Vos in their study from 2006 on ID swimmers who swam at Global Games 2004 (43).

This can explain the large difference in the strength scores in the two groups. If this is true for most ID athletes then this can also explain the lower maximal power that was found on athletes doing a repeated maximal power test (9) and the lower strength found in athletes competing on Global Games 2004 (40). It is clear that isometric muscle strength is related to swimming performance (29) although it is not clear what kind of slope the line of identity has but this weaker strength is clearly one of the reasons why ID swimmers swim as slow as they do. More strength can also relate to better and more efficient skill for swimmers in the water (34).

When the ID swimmers were asked why they did not take much part in the strength and endurance program on land, they all agreed that they did not feel well or secure in this environment that has been created with the needs of the WID swimmers in mind. It was noisy, chaotic and strange rules which they did not always understand where in place. When the coaches of the WID swimmers who had ID swimmers in their program where asked the same question, they all said, the ID swimmers did not like the weight room to much.

The greatest difference between the two groups was however found in actual swimming performance. In Figure 3 the swimming score for the ID swimmers has been converted to score based on world records for able body swimmers. (Direct comparison) In this case 100% was the mean performance of European swimmers corrected for age, gender and body characteristic. ID swimmers swim a lot and they have done so for many years. They have similar or better racing experience than the WID swimmers, but they are much slower. The only thing they score very low in is in strength measurements.

What this means for the ID population in that they are flexible enough to swim much faster, but they are either too weak and/or have too poor technique to use that skill to their advantage. Increased strength usually means a better chance to swim with better technique (29) but exactly how much is hard to tell. The trend in swimming coaching

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today is much more emphasis is on strength training than earlier, when flexible joints were considered very important (34).

So the answer to the first research question is, yes, there is a difference in the physical capacity between ID and WID swimmers. The ID swimmers are almost always weaker than WID swimmers. It is however not absolutely clear if this is because of the intellectual disability or if it is because of less training for ID swimmer.

End race results and Borge scale

It is clear from table 5 that ID swimmers are less stable in their end race results. The fluctuations within the groups in 200 m freestyle done in 50 m pool in this study are very similar to the fluctuations in the same race in 25 m pool where the changes between race 1-3 were 3.59% +/-1.48 for ID and 2.26% +/-1.55 for WID (42).

The WID group behaved very much as predicted from previous studies done with WID swimmers. Previous studies on stability in end race results for WID have shown that good swimmers can be expected to have about 1.4% difference in end race result between two meets (38). And further that the better the swimmers the less the variation. Finalists in that study showed less than 0.9% variance over two meets (38).

In many ways this is not what could be expected from hydrodynamic terms at least. The fact that water resistance increases with the square of the speed and therefore also the power output needed to achieve that speed might indicate different result (21). Only a slight difference in power output from the swimmer might cause a big change in the end result. Within the WID group this might not be a big issue, because they all swim in very similar speed. But there is however a great difference in the speed between ID and WID and we might speculate that ID swimmers should have easier task to be stable in their performance, at least from hydrodynamic perspective.

The fact that Borge scale hardly worked for the ID swimmers makes the result a little bit weaker. It is hard to determine the effort the ID swimmers put into their races but one thing is clear, their intentions were clear; they always meant to try their absolute best.

However we need to keep in mind that swims were ordered from fastest to slowest, but not in the time order they swam. It is interesting to look at what happens if we arrange the swims in time order. Both groups had the last meet as their national championship, where selection for the national team for each population was made. Six swimmers in the WID group did their best time at nationals but only 4 ID swimmers were able to do so at their meet. Usually the tension and stress is higher at these big meets. Some authors have pointed out that people with ID have problems coping with stress (28).Which can lead to poorer results at swimming meets where tension is high and much at stake. The line of identity through the average time in race 1 – 3 has the slope of 0.39 and R^2=0.653 for the ID and slope of 0.88 and R^2=0.99 for the WID. On average the ID swimmers in this study improved their time more than the WID swimmers at the same interval, but WID swimmers show much more linear trend towards their improvements. This is very similar results to that found in the study done in 25 m pool. Also there the national championship in short course was one of the meets analyzed. In that meet seven of eight WID swimmers did their best of the season but only three ID swimmers managed to do so. We cannot conclude that this is only because of the disability. Swimmers in both groups have swum similar number of competitive races; only most ID swimmers have done more international races so they could be expected to have more experience coping with these kinds of situations.

This all means simply that ID swimmers show greater variance between meets in end race results than WID swimmers despite having the same or better competition experience. The research question two is answered positively. Yes, swimmers with ID show greater variance between meets in end race results than swimmers without ID in 200 m freestyle race

Clean swimming speed, stroke rate and stroke length

The changes in average CSS between races were almost identical to the changes in end race results for both groups (Table 6). The changes in mid-pool speed were further statistically different between the two groups. CSS for ID swimmers simply changes more from meet to meet. The mean CSS for WID group in this study changed in a similar way between races as was seen in other studies on WID swimmers (22). The line of identity through the race means CSS between races in ID swimmers in this study has double the slope of that of the WID group.

The results from the 25 m pool study with the similar setup shows slightly different results. Changes in CSS are higher than the changes in end result (42) which can be explained by the 2 extra turns in 25 m pool.

These changes in mean CSS in the 50 m pool study were almost entirely related to changes in stroke rate for WID swimmers, but this relationship is not as clear in the ID group (Table 6). This is in agreement with previous findings in race patterns for ID swimmers (13). There was no statistical difference in stroke rate between the groups.

Although stroke length is much lower for ID swimmers, both groups showed stability in this variable between races. This means that the stroke mechanics of both groups are well established and to change the speed WID swimmers tend to change their stroke rate but ID swimmers have problem converting higher rate into higher speed.

The changes of race variables for WID swimmers within each race in this study were also very similar for WID swimmers as was found in previous studies (5; 16; 22). Clean swimming speed and stroke length decrease as the race progresses and swimmers try to maintain their speed by manipulating their stroke rate (Figures 4a, 4b, and 4c). The patterns for ID are also somewhat similar although there is more fluctuation in the stroke rate, again causing fluctuation in the clean swimming speed. The relationships between SL, SR and CSS are also not completely clear throughout the race (Figures 4a, 4b, and 4c) in agreement with other studies (13; 18).

We can conclude that changes in stroke rate are most relevant for within race changes in CSS at least for WID swimmers, but the relation is not so clear for ID

swimmers (Figures 4a, 4b, and 4c). Both groups try to maintain or even increase their stroke rate to maintain the swimming speed, but the pattern for ID swimmers is not so clear.

The correlation of race mean stroke length with mean CSS is -0.643 (r<0.05) for the WID but only -0.429 (r=0.14) in ID swimmers. This means that on average the fastest swimmers in the WID group take longer strokes but the relationship is not seen as clearly in the ID group.

Turning and starting

Turning proved to be very stable in both groups in this study as can be seen in Table 7 and even though WID are much faster in turning there was no interaction between the two groups and meets in this study as was found in previous studies on the same population racing the same event in 25 m pool (42). This can simply be explained by much fewer turns in 50 m pool that in the 25 m pool. There was much less variation in turning time than in clean swimming speed, stroke rate and even in stroke length both for ID and WID swimmers. It means that both groups are well trained and have well established turning patterns and perform them very similar every time. However, we see that the coefficient variance (CV) is higher for ID which relates to the fact that extreme values appear more frequently in that group. There are too few turns in 200m race in 50m pool to find correlation between extreme values and sequence of the turns, but it was clear that they appeared most frequently in the last turn when fatigue is usually highest. No extreme values were reported in the WID group.

Elite European swimmers use on average 21.88% +/-0.06 of their total race time doing the turns in 200m freestyle race (22). The WID swimmers in this study had almost the same percentages in their fastest race, 21.92% +/-0.06 but the ID swimmers are statistically slower in doing their turns 22.23% +/-0.10 (Table 7).

Several turn indexes were calculated. The results suggest that ID swimmers have trouble in the turning action (somersault) itself and much less so in the push-off. The turn is actually not only a complete somersault but also requires the swimmer to make a partial rotation about the long axis of the body to be able to push off the wall again and swim in

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the opposite direction on the front of the body. The turn does not require the swimmer to touch the wall with the hand. He or she has to judge the wall distance and carry out the turn at the best moment so that the feet and legs hit the wall in an optimal position to push off. Furthermore, most swimmers prefer one hand over the other when it comes to turning. A swimmer of course does not always get to the wall with the best hand forward. So the skill is complicated by itself and requires judgment only to be gained by experience. So when a skill requires some immediate adaptation to the situation or to do a multiple task, ID athletes have been shown to be slower (28).

Starting also proved to be more stable than the other race variables (SR, SL and CSS). A task such as starting, which is always performed the same way and without fatigue, does not seem to provoke any unstable pattern for ID swimmers. Further, no swimmer in this study was disqualified for false start in any race. This means again that they are well trained and have great experience in what they are doing. Extreme values where noted in the ID group, but these did not seem to be related to end race result or importance of the race. These findings support what was found in the study done on 200m freestyle race in 25 m pool (42).

All this means that it is mainly the greater variance in clean swimming speed for ID swimmers that contributes to the greater variance in the end result in this group, and further that it is mainly the poor relationship between stroke rate and CSS that is the cause of this variance, rather than instability in turns. This answers research question 3 and 4.

Relative changes from fastest race to slowest race

Most stability studies done on swimmers have only taken two swims into account, either changes between heats and finals or two races on different days. If the data from present study is analyzed only with the fastest and slowest race, we see that from Figure 5 that the ID swimmers are statistically more fluctuating in their performance in four out of six variables. This means that they are much less predictable in their performance than the WID population of swimmers. The WID swimmers in this study always performed within margins expected from other studies (22; 38).

When elite performance is evaluated, training, goal setting, quality of coaching and other points are evaluated. This usually means that stability follows (36). In the two populations studied here, stability only seems to be found in the WID group. Only stroke length and starting time show similar stability in ID and WID swimmers. Again stable stroke length indicates that the group has well established stroke mechanics. Stable start means that ID swimmers have no problem executing a well practiced task without fatigue.

The greatest changes appear in stroke rate which seems to be the main thing that ID swimmers have problem in controlling when they are trying to maintain race speed. This is the same as the study from the 25 m pool revealed (42). End race result and clean swimming speed are the only variables that show interaction between class and race, and they show almost the same difference in between fastest and slowest race (Figure 5). Turning is also statistically more unstable for the ID group than for the WID when we compare the fastest race with the slowest one.

Again it is not so clear why this difference is between the groups. Some part of the reason is less training, both in the water but mainly on land. It can only be speculated from these result that part of the reason for this difference comes from difference in intellectual skill, between the two groups.

Strong points and weaknesses in this study

The strong points of this study are that both groups had the same accessibility to training on land and in water and the same quality of coaching (same coaches). They also come from a community where disability sport is accepted as a competitive sport and with expectations for disabled athletes. There was no dropout in the study, and there was no interaction between the protocol of the study and the training or racing habits of participants. All swimmers kept their normal training and competition schedules through the entire period of the study. Both groups where examined and analyzed by the same person, which in a way at least means that if there are any systematic errors in the results, they should go across both groups.

The weak points on the other hand are mainly that we cannot say that both groups are identical in every way with the exception of one group having ID. The WID swimmers

are trained more and are faster, both in absolute and relative terms. This makes it hard to say exactly why the differences appear in the two groups. The relative few swimmers in each group also provided low statistical power. Using the IQ score as any correlation or reference point could not be done. This was not known for the WID athletes. However it is clear that within the ID group IQ score correlates rather well with performance level.

This group of ID swimmers has that in common that they have been accepted in to INAS-FID competitions. That means that they have IQ of 74 or lower, and that according to the questionnaire their disability is tampering their performance in sport. On the other hand there are many reasons for low IQ in people, and only some reasons have been shown to lead to reduced motor skill (32).

It was speculated that the control group should have included swimmers training less and swimming slower. It was not possible to find a group of WID swimmers who were the same age, trained 13 hours a week and did little land training. The absolute best performance of ID swimmer in this study only matches 11 year old children who have been training for 3 years. So this was never an easy task. In fact this is an important thing to keep in mind; WID swimmers are obviously much quicker to learn the skills in swimming.

Future research

What INAS-FID and IPC wants mainly to know are two things. First, does intellectual disability affect performance in sport and secondly, what kind of testing can be done to classify ID athletes so they can be accepted into the Paralympics Games? In this study we have answered the first question, at least partly, that ID swimmers behave in many ways differently from WID swimmers. They are much slower and less stable in their performance and from that perspective should be allowed to race in their own special class and compete with their peers just as other disabled athletes. On the other hand, this race analysis process cannot easily be used as a tool to classify swimmers into classes. A novice swimmer will swim slower and most likely be much less stable than a swimmer who has great experience in training and racing. Even though it would be clear that all participants were expert swimmers this method only indicates who do not belong in the class. If a swimmer gets really stable in all his race parameters and his overall

performance is similar to WID swimmer, then he does not belong in the competition class for ID swimmers (S14).

It is not clear what it is that makes ID swimmers have shorter stroke length, unstable stroke rate and generally worse at more complex actions in swimming. Studies on the fine skills in swimming, needs to be done with this group of swimmers. Swimming skills are very complex and it should be investigated where in the stroke cycle ID swimmers are weaker in comparison with WID swimmers. Anecdotal evidence indicates that it is more in the gliding phase and body posture than in other aspects of the stroke cycle. A simple study that examines the learning curve of ID and WID swimmers in mastering a task in water could be useful. Drag tests have been done on some Paralympics swimmers with a physical disability, which can easily be done both on ID and WID swimmers.

Today there is available an EMG (Electromyography) technique to evaluate the motor control of swimmers. A difference has been found between elite swimmers and novice swimmers with this technique which is related to better motor control with the elite swimmers. This can possibly show some difference between ID and WID swimmers as well, because motor control should in some way be linked with intellectual disability.

There is no simple solution to solve the requirement of having a test that can determine who can be in the S14 class. The test should be done on location at the big meets, or at least there should be some protest protocol that can be carried out at the major meets like the Paralympics. Today the Wechsler IQ test and a questioner are used for eligibility for INAS-FID. The Wechsler test is widely used and an internationally accepted test. It is comprised of verbal, performance and overall sections and an IQ score is given for each section. The number that is used is always the overall score, which is some average of the other sections. This test does not, therefore, really reflect the ability of individuals to perform a complex task. Further, every test needs to be adapted to each society and translated in to language of each subject. It is, therefore, not a feasible option as on-site test. The questionnaire INAS-FID uses can also be a really good tool, but it does not take a very intelligent person to figure out how to answer the questionnaire so his

swimmers will be eligible for the class. In other words it is rather easy to cheat when answering the questionnaire.

Some kind of motor control test needs to be developed that can be carried out on the side, to support the IQ test and questioner, which will always have to done at home.

Conclusion and recommendation

Four research hypotheses were initially presented to guide this study. The results showed that three of them are at least partially true. First, ID swimmers show less physical capacity than WID swimmers; secondly, ID swimmers have more variance between meets in end race result than the control group. Thirdly, this greater variance in end race result is mostly caused by variance in clean swimming speed which in turn in mainly caused by variance in stroke rate. The complex task of turning did not prove to be a major factor in variance in the end result for ID swimmers. The difference in speed, however, between two swimmers was more related to stroke length (SL) than stroke rate (SR), illustrating that all participants in both groups have well established stroke patterns.

Only a few authors have described the 200 m freestyle race in a manner presented in this study (5; 42). Swimming speed and stroke length, for all participants in all these studies, decreased as the race progressed. Stroke rate decreased very much in the beginning of the race, then stabilized in the middle and sometimes rose toward the end of the race. This is true regardless of disability or performance level.

The result from this study does not solve the problems INAS-FID and IPC are facing concerning ID athletes. People who really don't want ID swimmers in IPC can always argue that the population of ID swimmers in this study simply does not train enough. It can also be stated that the coaches of ID swimmers lack knowledge to maximize their performance.

What ID swimmers and their coaches must do is to match the WID population in every aspect of training, specially the land training. It is a vital point that people working with ID swimmers find a way to make them feel better in the weights room so that they can work on their maximum strength and muscle endurance which seems to be the main thing that sets them physically apart from WID swimmers. It is clear from this study and others on ID swimmers that this point is holding them back in swimming performance. It

is also the experience of many coaches working with ID swimmers that these swimmers have very little perception of the effort they are putting into both training and racing. They had no or very little feeling for the Borge scale for example. Use of heart rate monitors could be very helpful for this population of swimmers, both so that they can maintain correct work load in practice, but also to help them find the right race pattern.

Competition swimming is a complex sport that swimmers need to work hard to master the skill, and achieve the highest level of physical fitness. It is therefore very important that the coaches realize that ID swimmers are different from WID swimmers in many ways. They need a longer time to master certain skills, not only in practice but also in racing. The more complicated the skill the more time ID swimmers need to reach elite level and become stable in their performance. They can therefore not copy directly a swimming program for WID swimmers an implement it on ID swimmers, they need to be treated differently in many ways, even though their physical capacity is similar to most other swimmers.

Reference List

1.   DOE Workbook: Conducting accident investigations (revision 2) US Department of Energy. http://www.ed.doe.gov/csa/aip/workbook/ . 2006. 15-1-2006. Ref Type: Internet Communication

2.   INAS-FID. http://www.inas-fid.org/ . 2008. Ref Type: Internet Communication

3.   paralympic.org. http://www.paralympic.org/paralympian/20012/2001205.htm. 2008. Ref Type: Internet Communication

4.   Íþróttasamband fatlaðra. http://www.isisport.is/sersamb/if/ . 2008. Ref Type: Internet Communication

5.   Arellano R, Brown P, Cappaert J and Nelson RC. Analysis of 50-, 100-, and 200-m freestyle swimmers at the 1992 Olympic Games. *Journal of Applied Biomechanics* 19: 189-200, 1994.

6.   Butler L and Anderson S. Inspiring students to a lifetime of physical activity. *The Journal of Physical Education, Recreation & Dance* 73: 21-25, 2002.

7.   Carlton LG, Chow JW and Shim J. Variability in Motor Output and Olumpic Performers. In: *Movement System Variability*, edited by Davids K, Bennett S and Newell K. Champaign, IL: Human Kinetics, 2006, p. 85-108.

8.   Chengular SN and Brown PL. An analysis of male and female Olympic swimmers in the 200-meter events. *Canadian Journal of Sport Science* 17: 104-109, 1992.

9. Chia YHM, Lee KS and Teo-Koh SM. High intensity cycling performances of boys with and without intellectual disability 15. *Journal of Intellectual & Developmental Disability* 27: 191-200, 2002.

10. Collier DH. Instructional Strategies for Adapted Physical Education. In: *Adapted Physical Education and Sport*, edited by Winnick JP. Champaign IL: Human Kinetics, 2005, p. 109-130.

11. Craig AB, Jr. and Pendergast DR. Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. *Medicine and Science in Sports* 11: 278-283, 1979.

12. Craig AB, Jr., Skehan PL, Pawelczyk JA and Boomer WL. Velocity, stroke rate, and distance per stroke during elite swimming competition. *Medicine & Science in Sports & Exercise* 17: 625-634, 1985.

13. Daly D, Einarsson I, Van de Vliet P and Vanlandewijck Y. Freestyle race success in swimmers with intellectual disability. In: *Biomechanics and Medicine in Swimming X*, edited by Vilas-Boas JP, Alves F and Marques A. Porto, Portugal: Portuguese Journal of Sport Sciences, 2006, p. 294-296.

14. Daly D, Malone L and Vanlandewijck Y. Analysis of Sydney 2000 Paralympic Breaststroke Finalists. In: *Biomechanics and Medicine in Swimming IX*, edited by Chatard JC. Saint-Étienne, France: Publications de l'Université de Saint-Étienne, 2003, p. 277-282.

15. Daly D and Vanlandewijck Y. Some criteria for evaluating swimming classification. *Adapted Physical Activity Quarterly* 16: 217-289, 1999.

16.   Daly DJ, Djobova S, Malone LA, Vanlandewijck Y and Steadward RD. Swimming Speed Patterns and Stroking Variables in the Paralympic 100-m Freestyle. *Adapted Physical Activity Quarterly* 20: 260-278, 2003.

17.   Daly DJ, Malone LA, Smith DJ, Vanlandewijck Y and Steadward RD. The contribution of starting, turning, and finishing to total race performance in male Paralympic swimmers. *Adapted Physical Activity Quarterly* 18: 316-333, 2001.

18.   Daly, D. J., Malone, L. A., Vanlandewijck, Y., and Steadward, R. D. Analysis of the men's 100-m freestyle at the 1996 Atlanta Paralympic Games. In: *Biomechanics and medicine in swimming VIII*, edited by Keskinen, K. L., Komi, P. V., and Hollander, A. P, Jyväskyla, Finland, University of Jyväskyla. 1999,p. 309-314.

19.   Ells LJ, Lang R, Shield JPH, Wilkinson JR, Lidstone JSM, Coulton S and Summerbell CD. Obesity and disability - a short review 3. *Obesity Reviews* 7: 341-345, 2006.

20.   Emerson E. Underweight, obesity and exercise among adults with intellectual disabilities in supported accommodation in Northern England. *Journal of Intellectual Disability Research* 49: 134-143, 2004.

21.   Gerhart PM, Gross RJ and Hochstein JI. *Fundamentals of Fluid Mechanics*. Reading MA: Addison-Wesley Publishing Company, 1992.

22.   Haljand, R. LEN Swimming Competition Analysis 47.
http://www.swim.ee/competition/index.html . 2008.
Ref Type: Internet Communication

23.   Hogan A, McLellan L and Bauman A. Health promotion needs of young people with disabilities--a population study. *Disabil Rehabil* 22: 352-357, 2000.

24. International Paralympic Committee. *IPC: SAEC-SW swimming classification manual.* International Paralympic Committee (available from Mrs. Anne Green, email: anne.ipcswimming@bigpond.com), 1998.

25. Janell CM and Hillman CH. Expert Performance in sport. In: *Expert performance in Sport*, edited by Starkes JL and Ericsson KA. Champaign IL: Human Kinetics, 2003, p. 17-49.

26. Johannsson E, Arngrimsson SA, Thorsdottir I and Sveinsson T. Tracking of overweight from early childhood to adolescence in cohorts born 1988 and 1994: overweight in a high birth weight population
5. *Int J Obes (Lond)* 30: 1265-1271, 2006.

27. Kennedy P, Brown P, Chengular SN and Nelson RC. Analysis of male and female Olympic swimmers in the 100-m events. *International Journal of Sport Biomechanics* 6: 187-197, 1990.

28. Krebs PL. Intellectual Disabilities. In: *Adapted Physical Education and Sport,* edited by Winnick JP. Champaign IL: Human Kinetics, 2005, p. 133-154.

29. Mactavish JB and Dowds MJ. Physical activity and sport for individuals with intellectual disability. In: *Adapted Physical Activity*, edited by Steadward R, Wheeler GD and Watkinson EJ. Alberta: University of Alberta Press, 2003, p. 559-587.

30. Maglischo EW. *Swimming Fastest*. Champaign, IL: Human Kinetics, 2003.

31.   Mason, B. and Cosser, J. What can we learn from competition analysis. Sanders, R. and Youlain, H. *Proceedings of XVIII International Symposium of Biomechanics in Sports Applied Program:* Applications of biomechanical study in swimming. 75-82. 2000. Hong Kong, China, The Chinese University Hong Kong. Ref Type: Conference Proceeding

32.   Mohan A, Singh AP and Mandal MK. Transfer and interference of motor skills in people with intellectual disability 1. *J Intellect Disabil Res* 45: 361-369, 2001.

33.   Noble BJ, Borg GA, Jacobs I, Ceci R and Kaiser P. A category-ratio perceived exertion scale: relation to blood and muscle lactates and heart rate. *Medicine & Science in Sports & Exercise* 15: 523-528, 1983.

34.   Olbrecht J. *The Science of Winning - Planning, Periodizing and Optimizing Swim Training*. Overijse, Belgium: J. Olbrecht, 2000.

35.   Pelayo P, Sidney M, Moretto P, Willie F and Chollet D. Stroking parameters in top level swimmers with a disability. *Medicine & Science in Sports & Exercise* 31: 1839-1843, 1999.

36.   Salmela JH and Moraes LC. Development of Experties: The role of Coaching, Families and cultural contexts. In: *Expert Performance in Sports,* edited by Starkes JL and Ericsson KA. Champaign IL: Human Kinetics, 2003, p. 275-294.

37.   Siedentop D, Hastie P and van der Mars H. *Complete guide to sport education.* Champaign, IL: Human Kinetics, 2004.

38.   Stewart AM and Hopkins WG. Consistency of swimming performance within and between competitions
2. *Med Sci Sports Exerc* 32: 997-1001, 2000.

39.   Sweetenham B and Atkinson J. *Championship Swim Training*. Champaign, IL: Human Kinetics, 2003.

40.   Van de Vliet P, Rintala P, Fröjd K, Verellen J, Van Houtte S, Daly D and Vanlandewijck Y. Physical fitness profile of elite athletes with intellectual disability. *Scandinavian Journal of Medicine and Science on Sports* 16: 417-425, 2006.

41.   Van Tilborgh L, Daly D, Vervaecke H and Persyn U. The evolution of some crawl performance determinant factors in woman competitive swimmers. In: *Human growth and development*, edited by Borms J, Hauspie R, Scand A, Suzzanne D and Hebbelinck M. New York: Plenum Press, 1984, p. 666-676.

42.   Vanneste T. *Seasonal changes in race parameters in swimmers with intellectual disabilities* (Dissertation). Leuven, Belgium: Katholieke Universiteit Leuven, 2007.

43.   Versichel H and Vos L. *Race success in swimmers with intellectual disability* (Dissertation). Leuven, Belgium: Katholieke Universiteit Leuven, 2006.

Appendix A

BODY STRUCTURE CHARACTERISTICS

a. Material

- 3 tape measures,
- Table,
- Bench,
- Chair,
- Calibrated bathroom scale (always use the same scale)
- Caliper

b. Personnel: 1 test leader, 1 assistant, 1 secretary.

c. General instructions

- Body structure measurements are made on the right side.
- All are repeated 3 times and the mean is taken.
- All are made accurate to 0.1 cm (except nr 9, Body Weight, accurate to 0.5 kg).
- Check if the antropometer is held vertically.

1. HEIGHT

a. Material: Antropometer, wall.

b. Position of swimmer

The swimmer stands barefoot, back against the wall, heels together. Hands are held at the side with head erect, looking straightforward.

c. Measurement method

The antropometer is pressed gently downward on the highest point of the head (vertex).

2. ACROMION HEIGHT

a. Material: See 1.

b. Position of swimmer

The swimmer stands in the same position as in 1 and well balanced (shoulders horizontal).

c. Measurement method

The antropometer is pressed gently downward against the acromion (not the projection on top of the shoulder).

3. DACTYLION HEIGHT

a. Material: See 1.

b. Position of swimmer

The swimmer is in the same position as in 2, well balanced (shoulders horizontal) and the fingers are held together and extended.

c. Measurement method

The antropometer is pressed up against the longest fingertip.
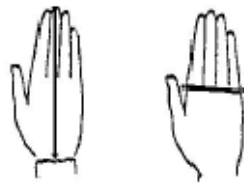
4. SITTING HEIGHT

a. Material: See 1 + bench or flat chair.

b. Position of swimmer

The swimmer sits on a bench, back against the wall, head erect, looking straightforward.

c. Measurement method

The antropometer is placed behind the swimmer and the distance from the bench to the head is measured.

5-6. HAND LENGTH / WIDTH

**a. Material:** Table and chair, caliper

b. Position of swimmer

The swimmer sits, with the hand on the table, palm upward.

c. Measurement method

- Length: the distance between the middle point on the first full crease in the skin on the wrist and the top of the middle finger is measured.

- Width: the distance between the most extreme bony projections on the sides of the palm is measured
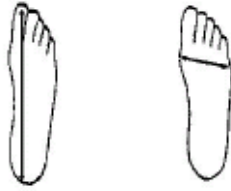
7-8. FOOT LENGTH / WIDTH

a. Material: Flat chair or bench, caliper

b. Position of swimmer

The swimmer is standing with the foot resting on a bench.

c. Measurement method

- Length: the distance from the longest toe to the heel is measured.

- Width: the width at the widest part of the ball of the foot is measured.

9. BODY WEIGHT

a. Material: Bathroom scale.

b. Position of swimmer

The swimmer stands completely still with both feet on the scale.

c. Measurement method

The body weight is read from the scale.

10. SHOULDER WIDTH (bideltoid)

a. Material: Caliper

b. Position of swimmer

The swimmer stands back against the wall, hands at the side.

c. Measurement method

The distance between the most lateral points of the deltoid muscle (= widest part of the shoulders!) is measured, without

compression. The end of the level is held against the tape measure and set against the deltoid muscle.

11. HIP WIDTH (biiliocrista)

a. Material: See 10.

b. Position of swimmer

The swimmer stands, back against the wall.

c. Measurement method

The distance between the widest points on the upper edge of the hip bone (the most lateral point on the crista iliaca) is measured.

12. CHEST DEPTH (arms upward)

a. Material: See 10.

b. Position of swimmer

The swimmer is standing arms stretched above the head, breath held (relaxed between inspiration and expiration).

c. Measurement method

The distance is measured between a point on the bottom third of the sternum and a point on the vertebrae at the same level.

13. ELBOW WIDTH (humerus)

a. Material: See 10.

b. Position of swimmer

The swimmer stands with the elbow flexed to 90°.

c. Measurement method

The distance between the widest bony points on the elbow (the most lateral points of the epicondyles of the humerus) is measured.

14. SKIN FOLD TRICEPS

b. Position

Standing.

c. Measurement method

The skin fold is taken vertically on the back of the arm, midway between the shoulder and the elbow.

15. SKIN FOLD SCAPULA

b. Position

Standing.

c. Measurement method

The skin fold is taken near the lower corner of the scapula, so that it runs outward and downward.

16. SKIN FOLD ABDOMEN

b. Position

Standing.

c. Measurement method

The skin fold is taken at a position about 3 cm above the spina iliaca anterior superior (hipbone running inward and downward toward the inside of the leg) in the direction of the navel. The skin fold runs parallel with this hipbone.

17. SKIN FOLD CALF

b. Position

Sitting.

c. Measurement method

The skin fold is taken on the inner side of the calf just above the maximal diameter and parallel to the length of the lower leg.

Appendix B

KENNARAHÁSKÓLI
ÍSLANDS

I   **Persónulegar upplýsingar (um sundmanninn)**

Raðnúmer

Fötlunarflokkur

II   **Árangur í sundi**   (Besti tími á síðustu 12 mánuðum)

100 m
bringusund

200 m
skriðsund

Hvert er aðalsundið þitt (má merkja við meira en eitt)

Skrið

Bringa

Bak

Flug

Fjór

III   **Æfingalegur bakgrunnur í lauginni**

1   Hvað hefur þú æft sund í mörg ár?

(Að minnsta kosti 3 tíma á viku, 6 mánuði á ári)

2   Hvað hefur þú æft mikið í lauginni síðustu 12 mánuði?

Fjöldi mánaða

Meðaltal klst. á viku?

Meðaltal km. á viku?

IV **Æfingalegur bakgrunnur á landi**

1   Hvað hefur þú æft mikið á landi síðustu 12 mánuði?

Þol (hlaup, hjól, leikir

.....)   Mánuðir ?

                                             Klst á viku ?

Styrkur   Mánuðir ?

                                             Klst á viku ?

Liðleiki   Mánuðir ?

                                             Klst á viku ?

V **Æfingaumhverfi**

1   Hvernig er æfingahópur þinn samansettur?

Æfi aðeins með öðrum fötluðum

Æfi mest með fötluðum en smá með ófötluðum

Æfi jöfnum höndum með fötluðum og ófötluðum

Æfir mest með ófötluðum en smá með fötluðum

Æfir alfarið með

ófötluðum

2   Hlýtur þú einhvern fjárhagslegan styrk til að stunda æfingarnar?

                                                        Já, é get einbeitt sér alfarið að æfingum

                                                        Ég fær nokkuð, en þarf að greiða eitthvað sjálfur

                                                        Ég fæ helstu kostnaðarliði greidda

                                                        Ég fæ nánast ekkert

                                                        Nei, ég ekki

                                                         neitt

3   Hefur þú gott aðgengi að æfingalauginni?

                                                        Já, mjög gott, allt sem ég þarf

                                                        Já þetta er nokkuð gott

                                                        Ágætt

                                                        Nei, ég þyrfti mun betra

                                                        Nei, ég kemst nánast ekkert í laug

4   Hefur þú gott aðgengi að annarri æfingaaðstöðu?

                                                        Já, mjög gott, allt sem ég þarf

                                                        Já þetta er nokkuð gott

                                                        Ágætt

                                                        Nei, ég þyrfti mun betra

                                                        Nei, ég kemst nánast ekkert í landþjálfun