International
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Committee

Chapter 4. 3 - Position Statement on background and scientific rationale for classification in Paralympic sport

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International Paralympic Committee

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Abstract

The Classification Code of the International Paralympic Committee (IPC), inter alia, mandates the development of evidence based systems of classification. This paper: provides a scientific background for classification in Paralympic sport; defines evidence-based classification; and provides guidelines for how evidence-based classification may be achieved.

Classification is a process in which a single group of entities (or units) are ordered into a number of smaller groups (or classes) on the basis of observable properties that they have in common and taxonomy is the science of how to classify. Paralympic classification is interrelated with systems of classification used in two fields:

- Health and Functioning: The International Classification of Functioning, Disability and Health (ICF) is the most widely used classification in this field. To enhance communication Paralympic systems of classification should use language and concepts that are consistent with the ICF;

- Sport: Classification in sport reduces the likelihood of one-sided competition and in this way promotes participation. Two types of classification are used in sport – Performance Classification and Selective Classification. Paralympic sports require Selective Classification systems, so that athletes who enhance their competitive performance through effective training will not be moved to a class with athletes who have less activity limitation, as they would in a performance classification system.

- Classification has a significant impact on which athletes are successful in Paralympic sport, but unfortunately issues relating to the weighting and aggregation of measures used in classification pose significant threats to the validity of current systems of classification.

- The IPC Classification Code mandates the development of evidence-based systems of classification, an evidence-based system being one which: the purpose of the system is stated unambiguously; and empirical evidence indicates the methods used for assigning class will achieve the stated purpose. To date, one of the most significant barriers to the development of evidence-based systems of classification has been absence of an unambiguous statement of purpose. To remedy this, all Paralympic systems of classification should indicate that the purpose of the system is to promote participation in sport by people with disabilities by minimising the impact of impairment on the outcome of competition. Conceptually, in order to minimise the impact of impairment on the outcome of competition, each classification system should:

- Describe eligibility criteria in terms of:
  - type of impairment; and
  - severity of impairment;

- Describe methods for classifying eligible impairments according to the extent of activity limitation they cause.

To classify impairments according to the extent of activity limitation they cause requires research which develops objective, reliable measures of both impairment and activity limitation and investigates the relative strength of association between these constructs in a large, racially representative sample. The paper outlines a number of objective principles which should considered when deciding how many classes a given sport should have: the number of classes in a sport should not be driven by the number of athletes in a sport at a single time-point.

Background

The International Paralympic Committee (IPC) is the global governing body of the Paralympic Movement, as well as the organiser of the Summer and Winter Paralympic Games. There are 20 Paralympic summer sports, and four winter and these are presented in Table 1, together with Wheelchair Dance Sport which is not contested at the Paralympic Games but which is governed by the IPC. As indicated, the IPC acts as international federation for nine sports (eight Paralympic and one non-Paralympic), while the remaining 17 Paralympic sports are governed by international federations which are structurally independent, but which have been admitted to the membership of the IPC. These international federations comprise International Organisations of Sport for the Disabled (IOSDs) which provide sports opportunities for people with specific disabilties (e.g., cerebral palsy or vision impairment); and International Sport-specific federations (e.g., Union Cycliste Internationale or International Wheelchair Basketball Federation).

In November 2007, the General Assembly of the IPC approved the IPC Classification Code. The Code provides comprehensive guidelines, policies and procedures for the conduct of classification in sports governed by the IPC or its member federations. (See Table 1 at the end of the document)

From a sports science perspective the Code is significant because it explicitly mandates the development of evidence-based classification systems (Code Section 15.2). This position stand has a twofold purpose:

- To provide a theoretically-grounded description of the scientific principles underpinning classification in Paralympic sport; and

- To define the term evidence based classification and provide guidelines for how it may be achieved.

What is classification?

Classification is a process in which a single group of entities (or units) are ordered into a number of smaller groups (or classes) on the basis of observable properties that they have in

common.[1,2] Taxonomy is the science of how to classify, its principles, procedures and rules.[2] It is applied in most scientific fields to develop systems of naming and ordering that facilitate communication, understanding and identification of inter-relationships

Swedish biologist Carl Linnaeus (1707-1778) is considered the father of taxonomy in the natural sciences.[3] In the tenth edition of System Naturae (1758), Linnaeus introduced a system of binomial nomenclature that was parsimonious yet informative, vastly improving communication in botanical science. For example, the Linnaean term for the European Red Current, 'Ribes rubrum' is a considerably more useful term than 'rossularia, multiplici acino: seu non spinosa hortensis rubra, seu Ribes officinarium', the most widely accepted alternative of the day. Linnaean classification is still the basis upon which life on earth is classified.

As a science in its own right, taxonomy is made meaningful through its application in other fields of science[2] such as pathology, botany and zoology for classification of diseases, plants and animals respectively. The Paralympic Movement provides competitive sporting opportunities for people with a range of impairments and, as such, is interrelated with systems of classification used in two fields:

1. Health and Functioning
2. Sport

The following sections describe taxonomic principles from these two fields that are relevant to classification in Paralympic sport.

Classification in health and functioning

The first internationally recognised system for classification of health and functioning was the International classification of impairments, disabilities, and handicaps (ICIDH), published by the World Health Organisation (WHO) in 1980. In 2001 the ICIDH was revised and re-named the International classification of functioning, disability, and health (ICF). Internationally, the ICF is currently the most widely accepted classification of health and functioning. It is a broad, multi-purpose classification that provides a standardised language and structure that may be applied to describing and understanding health related functioning in a wide variety of contexts and

sectors. Further information, including copies of the ICF, is available at: http://www.who.int/classifications/icf/en/.

In 2002, Tweedy [4] described the taxonomic relationship between the ICF and Paralympic classification. The relationship is presented graphically in Figure 1, which maps the domains relevant to Paralympic sport against the comprehensive ICF structure. Tweedy [4] proposed applying the language and structure of the ICF to the context of Paralympic classification and identified several advantages of doing so, including:

- ICF definitions for key terms are clear, unambiguous and internationally accepted. It has been empirically demonstrated that clear definitions enhance the inter-rater reliability of classification systems, particularly when the systems are used by people from a variety of professional and national backgrounds [2];
- the concepts of functioning and disability that are described in the ICF are contemporary and internationally accepted, including the inter-relationship between impairment and activity which is central to Paralympic classification; and
- the key terms and concepts of the ICF are described in six languages – English, French, Spanish, Russian, Chinese and Arabic – and therefore people from a range of non-English speaking backgrounds can learn about the key aspects of this System in their own language, thereby removing a significant barrier to international understanding of Paralympic classification.

Because of these advantages, the IPC Classification Code uses the language and definitions of the ICF. To be consistent, Paralympic classification systems should also conform to ICF language and structure. The remainder of this manuscript uses terms as defined by the ICF, the most important of which are presented in the Glossary. (see Figure 1 at the end of the document)

Classification in sport

Competition is a defining feature of sport and one of several factors that differentiate sport from other physical activities such as exercise, activities of daily living or recreation.[5] Moreover,

competition is known to be a potent social factor that motivates many thousands of people to play sport.[6, 7] However, when competition is one-sided or predictable, motivation to participate in sport is reduced, particularly among the unsuccessful.

Classification in sport reduces the likelihood of one-sided competition and in this way promotes participation. Two main forms of classification are used in sport:

- Performance Classification; and
- Selective Classification.

Performance classification

Examples of performance classification include the handicap system used in golf, the belt system used in several martial arts and the grading system used to organise competition in football codes (e.g., soccer, rugby and American football). These systems of classification group competitors according to their performance in that sport – competitors who perform very well compete together and those who are less accomplished also compete together. In taxonomic terms, the unit of classification is sports performance. While competitors within a class have a common level of performance, they may vary widely in age and body size, be males or females and, in principle, be disabled or non-disabled. In a performance classification system, competitors who improve their performance through enhanced fitness, skill acquisition or other means are reclassified to a higher performing class. Furthermore, because performance is the basis upon which competitors are placed into classes, competition is usually close and competition results can be used assess the validity of the classification methods – when competition is close and results are not predictable, the methods used to classify are valid.

Note that many performance classification systems have a "ceiling" – once competitors have reached a certain level of accomplishment, they are no longer classified. For example, golf players with a handicap of zero – or scratch – all compete together. They are not divided into players who only just able to make par and those who shoot well below par.

Selective classification

In contrast to performance classification, the unit of classification in selective classification is not performance but a specified performance determinant or set of determinants (i.e., factors known to be strongly predictive of performance). Three types of selective classification are commonly used in modern sports: age-based classification (e.g., age divisions in junior sport and masters sport), size-based classification (e.g., weight divisions in boxing, wrestling or judo) and sex-based classification (e.g., any sport in which males and females compete separately). The units of classification in these examples are, respectively, age, body weight and sex.

The effect of selective classification systems is to minimise the impact of the unit/s of classification on the outcome of competition. For example in an 800m footrace for girls aged 13 years, the impact of sex and age-related maturation on the outcome of competition is minimised, and the relative impact of other performance determinants – training background, psychology and physiology – is increased. Note that selective classification does not eliminate the impact of the units of classification – maturation among 13 year old girls can vary considerably – but their impact is typically reduced.

There are other important differences between performance classifications and selective classifications. Firstly, there is generally no ceiling in selective classification systems – they are applied from grass-roots participation to the highest international level. Secondly, if a competitor in a selective classification system improves their performance through training, their class does not change, as it might in a performance classification system. In selective classification systems, effective training increases a person's competitive standing within their class. Finally, because selective classification systems only control for the effect of a small number of specified performance determinants, performance levels within a given class may vary widely. Consequently, while competition results can be used to evaluate the validity of methods used in a performance classification system, they provide only weak evidence in relation to selective classification systems. The following hypothetical example from the sport of rowing illustrates this point.

Rowing has two weight-based classes: light-weight (mean crew mass <70kg and maximum individual weight of 72.5kg) and heavy-weight (no weight restriction). In a given season, an excellent light-weight rowing crew might consistently finish three boat-lengths in front of their nearest competitors and may even row faster times than some heavy-weight rowing crews.

However these results do not constitute evidence that the crew has been mis-classified. To determine whether the crew had been classified correctly would require that a suitably qualified official weighed each crew member on a correctly calibrated set of scales. The results would then be checked to see wether the individual and combined body weights of the crew members met the guidelines determined by the International Rowing Federation (FISA).

As the descriptions above make clear, both Performance Classification systems and Selective Classification systems can be said to promote participation by providing a framework for fair and equitable competition. However, the IPC is committed to the development of Selective Classification systems, not Performance systems.

Classification in Paralympic sport

Background

Founded by Dr. Ludwig Guttmann in the 1940s, Paralympic sport originated as an extension of the rehabilitation process and during the early years of the Paralympic Movement classification was medically based. The organisational structure of medically-based classification systems reflected the structure of a rehabilitation hospital, with separate classes for people with spinal cord injuries, amputations, brain impairments and those with other neurological or orthopaedic conditions. Athletes received a single class based on their medical diagnosis, and competed in that class for all sports – athletics, swimming, archery and any other sports offered. An athlete with a complete L2 spinal cord injury – resulting in lower limb paresis but normal arm and trunk power – would compete in a separate wheelchair race from a double above-knee amputee because their medical diagnosis was different. The fact that the impairments resulting from their medical condition caused roughly the same activity limitation in wheelchair propulsion was not considered in the classification process because classification was based on medical diagnosis.

As the Paralympic Movement matured, sport ceased to be a mere extension of rehabilitation and became important in its own right. The focus on sport, rather than rehabilitation, drove the development of functional classification systems. In functional systems, the main factors that determine class are not diagnosis and medical evaluation, but how much the impairment of a person impacts upon sports performance. For example, in athletics, an athlete with a complete

L2 spinal cord injury now competes in the same class as a double above knee amputee (class T54). This is because these impairments have an impact on wheelchair propulsion that is approximately the same. Currently most Paralympic sports use systems of classification that are described as functional, a notable exception being the classification system used by the International Blind Sports Federation which remains medically-based.

In contrast to the medical classification approach, in which athletes competed in the same class for all sport, functional systems of classification are necessarily sports-specific. This is because any given impairment may have a significant impact in one sport and a relatively minor impact in another. For example the impact that bilateral below elbow amputation has on swimming is relatively large compared with the impact on distance running. Consequently, in sport specific, functional classification systems, an athlete with such an impairment would compete in a class that had relatively greater activity limitation in swimming than they would in track athletics.

Historically the transition from medical to sports-specific, functional classification systems began in the late 1970s, but there was considerable debate surrounding the relative merits of the medical and functional approaches and consequently the transition was slow.[8] One feature of early functional systems was that they comprised less classes than the existing medical systems.[9] Event organisers favoured fewer classes because the complexity of event organisation was significantly reduced. In 1989 the bodies responsible for organising the Barcelona Paralympic Games – the IPC and the Barcelona Paralympic Organising Committee – signed an agreement which stipulated that all Paralympic sports contested at the 1992 Barcelona Paralympic Games were to be conducted using sports-specific functional classification systems.[8] This administrative decision greatly accelerated the transition to functional classification systems.

At the time of this decision many sports had not begun to develop functional systems so, given the short time-frame and the absence of relevant scientific evidence, the classification systems that were developed were necessarily based on expert opinion. Within each of the sports, senior Paralympic classifiers from a diverse range of backgrounds – medical doctors, therapists, athletes and coaches – lead the development of functional systems of classification.

Current Paralympic classification

Since the widespread adoption of functional systems of classification, Paralympic sport has continued to mature rapidly. Currently there are more than 15,000 registered competitors with the international governing bodies of the 25 Paralympic sports, and a much larger (but indeterminate) number of athletes compete at local and regional level in their home countries but are not registered internationally. At the elite level, successful Paralympic athletes are receiving increasing peer and community recognition and many receive commercial sponsorship and other financial rewards.

It is well recognised that the classification an athlete is assigned has a significant impact on the degree of success they are likely to achieve. Unfortunately however, Paralympic classification and classification research have not matured as rapidly as other areas of Paralympic sport and current Paralympic classification systems are still based on the judgement of a small number of experienced classifiers, rather than empirical evidence. As a consequence, the validity of the methods used in functional classification systems is often questionable.

Threats to the validity of current classification methods

In some instances classification methods have considerable face validity. For example, in a range of Paralympic sports (e.g., wheelchair tennis, swimming, sailing and athletics) athletes with a complete spinal cord injury at C7 all compete in the same class, and this is a justifiable grouping because the nature and distribution of impairments caused by a C7 injury will be approximately the same for all people and therefore the injury will have a similar impact on performance in sport. Moreover, lower lesion level is associated with reduced activity limitation and consequently athletes with a complete T8 lesion will compete in a different class to those with a C7 lesion. The methods for assigning class in the cases described is based on medical diagnosis and confirmatory clinical evaluation of muscle strength, together with observation of the athlete performing a range of sports-specific and non sports-specific tests. These methods are typical of those used in many functional classification systems and, for the cases described, the methods appear to be valid. However, as the following paragraphs illustrate, closer scrutiny indicates that there are significant threats to the validity of these methods.

In general, threats to the validity of functional classification methods result from two separate but related measurement issues:

- Measurement weighting; and

- Measurement aggregation.

The following illustrations of weighting and aggregation issues are based upon the current classification system for wheelchair racing for athletes affected by impaired strength.[10] However the principles apply across the classification systems used in Paralympic sports. There are four class profiles for wheelchair racing – T51, T52, T53 and T54 – the T indicating the classes are for track racing and 51-54 indicating progressively decreasing severity of impairment. The class profiles are written in terms of loss of strength and may be summarised as follows:

- T51: equivalent activity limitation to person with complete cord injury at cord level C5-6. (elbow flexion and wrist dorsiflexion strength to grade 5, a decrease of shoulder strength especially pectoralis major, and triceps muscle power from grade 0-3);
- T52: equivalent activity limitation to person with complete cord injury at cord level C7-8 (normal shoulder, elbow and wrist strength, poor to normal finger flexors and extensors and wasting of the intrinsic muscles of the hands);
- T53. equivalent activity limitation to person with complete cord injury at cord level T1-7 (normal arm strength with little or no innervation of abdominals and lower spinal muscles);
- T54: equivalent activity limitation to person with complete cord injury at cord level T8-S4 (normal arm strength with a range of trunk strength extending from partial trunk control to normal trunk control).

Measurement weighting

Measurement weighting refers to the relative influence of individual measures of impairment on the classification outcome. Based upon the profiles above, classification of an athlete who presents with a complete cord injury at T2 would entail confirmatory diagnostic tests and clinical evaluation of strength using manual muscle testing as described by Daniels and Worthingham [11] and the resulting class would be T53. However the case of a person with a C6 incomplete injury who has some innervation of abdominals and lower spinal muscles, as well as impaired strength in the upper limbs is more complicated. Such a person has the same type of impairment as described in the class profile – impaired strength. However the distribution of the impairment is a mixture of the class descriptions. Consequently three main outcomes are possible:

- T52: this class will be assigned if the disadvantage caused by having less arm strength than T53 athletes is considered to be greater than the advantage conferred by superior trunk strength;
- T53: this class will be assigned if the disadvantage caused by having less arm strength than T53 athletes is considered to be equal to the advantage conferred by superior trunk strength;
- T54: this class will be assigned if the disadvantage caused by having less arm strength than T53 athletes is considered to be less than the advantage conferred by superior trunk strength.

In the case described, evidence-based decision making requires knowledge of the relative importance – or "weight" – of the trunk and arm muscles in relation to wheelchair propulsion. This knowledge would permit individual strength impairment scores to be meaningfully combined into a single 'wheelchair-specific strength impairment score', allowing athletes with different patterns of impairment to be meaningfully compared. Currently no such evidence exists and therefore decisions are made based on expert opinion. Opinion is usually informed by manual muscle testing of individual muscle groups, observation of sports specific and non-sports specific tasks and assessment of training history. [10]

Figure 2 (see Figure 2 at the end of the document) presents a hypothetical data set, plotting "wheelchair-specific strength impairment" (x-axis) against wheelchair racing performance (y-axis). These data indicate that increasing impairment is associated with slower wheelchair racing time, but that the relationship is curvilinear: small changes in impairment on the left side of the graph are associated with relatively large changes in performance, while changes in impairment of a similar magnitude on the right side of the graph are associated with very small changes in performance. The hypothetical strength impairment associated with a complete T2 spinal cord injury is indicated, as are the three relative strength impairment scores associated with a C6 incomplete injury: C6a causing greater impairment than T2; C6b the same; and C6c less.

Measurement aggregation

Challenges with aggregating measurements in classification are highlighted when a system classifies two or more different impairment types. Consider the case of a person with a complete spinal cord injury at T2 and right elbow extension deficit resulting from a co-occurring orthopaedic injury. In the absence of the elbow injury, the athlete would clearly fit in class T53.

However the co-occurrence of a second type of impairment – decreased range of movement (ROM) – leads to two possible outcomes:

T52: this class will be assigned if the disadvantage caused by reduced elbow ROM in the right arm causes the same or more disadvantage than the bilateral arm weakness experienced by athletes in this class;

T53: this class will be assigned if the disadvantage caused by reduced elbow ROM in the right arm is relatively minor, and causes less disadvantage than the bilateral arm weakness experienced by athletes in the T52 class.

In this case evidence-based decision making not only requires knowledge of the relative importance of impaired elbow ROM and strength, but a valid means of summing – or aggregating – these scores, which are measured in different units: impaired ROM, measured in degrees; and impaired strength, currently measured using a 0-5 ordinal scale.[11] Evidence based aggregation would permit results from different impairment types to be meaningfully combined into a single 'wheelchair-specific impairment score', which would be the basis of class allocation. Currently no such evidence exists and therefore expert opinion is required.

Figure 3 (see Figure 3 at the end of the document) presents a hypothetical data set, plotting "wheelchair specific impairment" (x-axis), a score based on aggregation of measures of wheelchair specific strength and range of movement, against wheelchair racing performance (y-axis). These data indicate increasing impairment is associated with slower racing time. The hypothetical impairment score associated with a complete T2 cord injury is indicated, as are the two relative impairment scores for T2 cord injury combined with impaired elbow ROM: T2 + elbow1 causing greater impairment and T2 + elbow2 causing a negligible increase in impairment.

Developing evidence-based systems of classification – taxonomic requirements

The challenges associated with measurement weighting and aggregation highlights the principal shortcomings in current approaches to classification. The IPC recognises the need for systems of classification that are evidence-based and explicitly mandates the development of

such systems in Section 15 of the Classification Code.[17] This section establishes the taxonomic pre-requisites needed for the development of sports-specific, evidence-based systems of classification.

What is an evidence-based system of classification?

In Paralympic sport, an evidence-based system of classification is one which:

- the system has a clearly stated purpose; and
- empirical evidence indicates that the methods used for assigning class will achieve the stated purpose.

To date, one of the most significant barriers to the development of evidence-based systems of classification is that many systems of classification either do not have stated purpose or have a statement of purpose that is ambiguous. For example many classification systems simply state that the purpose is to provide "fair and equitable competition". This statement is ambiguous because, as identified previously in this paper, fair and equitable sports competition can be achieved by both Performance Classification systems and Selective Classification systems. However the IPC is committed to the development of Selective Classification systems, so that athletes who enhance their competitive performance through effective training will not be moved to a class with athletes who have less activity limitation – as they would in a performance classification system – but will be rewarded by becoming more competitive within the class they were allocated.

The purpose of classification

To facilitate development of evidence-based systems of classification, all Paralympic systems of classification should indicate that the purpose of the system is to promote participation in sport by people with disabilities by minimising the impact of eligible types of impairment on the outcome of competition. This statement of purpose was first proposed by Tweedy [4] and is consistent with Section 2.1.1 of the Code which states that "Classification is undertaken to ensure that an athlete's impairment is relevant to sports performance and to ensure that the athlete competes equitably with other athletes". From a taxonomic perspective, adopting the proposed statement of purpose is critical because "impairment" is explicitly identified as the unit of classification, clearly aligning Paralympic classification with other Selective Classification

systems used in sport (e.g., age, sex and body weight). When impairment is the unit of classification then the relative impact of other performance determinants – for example, volume and quality of training and psychological profile – is increased and the athletes who succeed will do so because they are stronger in these areas, rather than because they have an impairment that causes less activity limitation.

Conceptually, in order to minimise the impact of impairment on the outcome of competition, each classification system should:[4]

- Describe eligibility criteria in terms of:
  - type of impairment; and
  - severity of impairment;
- Describe methods for classifying eligible impairments according to the extent of activity limitation they cause.

These three dimensions of the purpose of classification are expanded under the headings below.

Defining eligible types of impairment

Sports should clearly identify which impairment types are eligible and define them according to the ICF codes. An example of the outcome of this exercise is presented in the IPC Athletics Classification Project for Physical Impairments.[10] To date only ten major types of impairment have been classified in Paralympic sport, these being vision impairment, impaired strength, impaired range of movement, limb deficiency, leg length difference, hypertonia, ataxia, athetosis, short stature and intellectual impairment (see Figure 1). Section 5 of the Code indicates that the type of impairment must be permanent,[17] indicating that it should not resolve in the foreseeable future regardless of physical training rehabilitation or other therapeutic interventions.

It is important to note that many health conditions that cause eligible impairment types affect multiple body structures and functions. For example, in addition to impaired strength, spinal cord injury may also result in impaired sensation (tactile sensation, proprioception or pain), impaired thermoregulatory function and impaired cardiac function. While some of these associated impairment types may have a significant impact on sports performance, expansion

of the types of impairment that are classified in Paralympic sport has the potential to have a significant impact on the culture and fabric of Paralympic sport and should therefore be approached cautiously. Furthermore, every Paralympic sport does not classify all major impairment types and nor are they obliged to. For example, vision impairment is not currently classified in wheelchair sports, and loss of strength is not assessed in judo or goalball. Which of the ten impairment types is classified in a given Paralympic sport is a matter for each sport to decide. Once decided, the impairment types classified should be clearly stated.

Note that while it is theoretically possible to develop systems of classification in which people with all 10 types of impairment compete together, this approach is not favoured by the IPC.

Rather, as Tweedy has previously proposed,[12] there are sound taxonomic reasons for treating the 10 eligible impairment types as at least three distinct groups: a) biomechanical impairments, comprising the eight impairments that cause activity limitations that are biomechanical in nature – impaired strength, impaired range of movement, limb deficiency, leg length difference, hypertonia, ataxia, athetosis, and short stature; b) vision impairments and c) intellectual impairments. Biomechanical impairments may also be referred to as neuromusculoskeletal impairments (which is consistent with the ICF but which is less informative in a sports context) or physical impairments (which is simple but less precise).

Defining eligible impairment severity

Section 5 of the Code indicates that in order to be eligible, an impairment must impact on sports performance.[17] To ensure that only impairments which impact on the sport are eligible, each Paralympic sport should develop minimum disability criteria. More specifically, each Paralympic sport should identify those activities that are fundamental to performance in that sport, and then operationally describe criteria for each eligible impairment type that will impact on the execution of those fundamental activities. For example, determination of minimum disability criteria for vision impairment in alpine skiing should be set by analysing the vision requirements for optimum downhill performance - visual acuity, visual field, contrast sensitivity etc – and then, once they have been identified, developing an operational description of the minimum vision impairment/s that will sufficiently compromise those requirements to be considered eligible.

There are two important consequences arising from accurately described minimum disability criteria:

- It will be possible for an athlete to have an eligible type of impairment but to be ruled ineligible because the impairment does not meet the relevant minimum disability criterion. For example, while a person who has had a single toe amputated is technically an amputee (an eligible type of impairment), the impairment does not cause sufficient activity limitation in running and therefore does not meet the minimum disability criteria for IPC Athletics [10]; and
- Minimum disability criteria will be specific to each sport. Consequently it will be possible for a person to have an impairment that is eligible in one sport, but not in another.

Note that minimum disability criteria should describe impairments that directly cause activity limitation in the sport and should exclude impairments that may cause activity limitation in training but do not directly impact on activities that are fundamental to a sport. For example, although the loss of the fingers on one hand will cause activity limitation in certain resistance training exercises considered important in sprinting (e.g. the snatch and the power clean), the impairment will cause negligible activity limitation in the sprint events themselves and therefore such an impairment is not eligible in IPC Athletics.[10]

To some extent determining how much activity limitation will be sufficient is affected by sports culture and more than one view may sometimes be considered valid. Consequently determination of minimum disability criteria should draw on empirical evidence when it is available, but also ensure that it reflects the views of key stakeholders in the sport – athletes, coaches, sports scientists and classifiers.

Classifying impairments according to extent of activity limitation caused

Impairments which meet the eligibility criteria should be divided into classes according to how much activity limitation they cause. To date a number of other phrases have been used to describe the conceptual basis of classification in Paralympic sports. Table 2 identifies two of the main ones and illustrates why each is not suitable. Note that while it is common to refer to "classifying athletes", the IPC takes this opportunity to reinforce that the unit of classification in Paralympic systems should be impairments, not athletes. This distinction is important because it reinforces that each athlete is a unique, sentient human being whose diversity and individuality cannot be captured by assigning a label or a class.[4,12]

[see Table 2 at the end of the document]

Practical implications

A sound taxonomic structure is a necessary pre-requisite for the development of evidence-based systems of classification because it permits the formulation of research questions that can be addressed using conventional experimental science. Paralympic sports seeking to develop evidence-based systems of classification should revise their current systems in light of the information presented in this section. The opening sections of the IPC Athletics Classification Project for Physical Impairments; Final Report – Stage 1[10] provide a working example of how a classification manual can be taxonomically structured so as to permit the experimental research needed to develop an evidence-base.

Developing evidence-based systems of classification – research needs

When systems of classification have the necessary taxonomic structure, including identification of the unit/s of classification and an unambiguous statement of purpose, the task of developing an empirically evaluating methods of classification through research can be addressed.

Fleishman and Quaintance [2] identify two types of classification research:

- Product-focused research, which evaluates the relationships between and within the formal set of classes or categories that results from classification; and
- Process-focused research which includes theoretical work establishing the taxonomic principles underpinning classification systems and empirical research which evaluates the validity of the methods used to place the units into classes.

Development of evidence-based systems of classification requires process-focused research. The remainder of this section illustrates why product-focused research has limited capacity to contribute to development of evidence-based systems of classification and expands upon the process-focused research that is required.

Product-focused research

Product-focused research is of value, but only once evidence-based systems of classification are in place. Examples of previously conducted product-focused research include evaluation of intra- and inter-classifier reliability and inter-class performance comparisons.[13-16] Figure 4 presents a typical product-focused analysis – a performance comparison of male athletes in four wheelchair racing classes. The y-axis indicates performance (sec) for four distances – 100m, 200m, 400m and 800m; and the x-axis indicates wheelchair racing class, T51 being the most impaired and T54 being the least. While these data clearly demonstrate an inverse relationship between class and performance, they provide only weak evidence that classification in wheelchair racing is valid. This is because there are at least three possible explanations for the results, these being that athletes are classified according to:

- how much their impairment affects performance
- racing performance alone; or
- a combination of the above.

It is critical that when researchers aim to develop and validate evidence-based classification systems, they utilise research designs that validate a classification process, rather than evaluate classification product.

[See Figure 4 at the end of the document]

Process-focused research – what is required?

It has already been established that a necessary pre-requisite for the development of evidence-based systems of classification is an unambiguous statement indicating that the aim of the system is to classify eligible impairments according to the extent of activity limitation they cause. This statement of purpose provides clear direction to researchers aiming to develop evidence-based systems of classification. The initial step requires development of objective, reliable methods for measuring both of the core constructs – impairment and activity limitation:

- Measurement of impairment: to date measurement of impairment in classification has largely been non-instrumented and has depended heavily on clinical judgement, particularly in the

biomechanical impairments. In some instances these may still be the most appropriate methods, however researchers should explore the use of instrumented measures which are simple, readily available which are more objective and less dependent on user judgement. Criteria for valid tests of impairment are as follows:

- Impairment specific: the test should measure effect of only one impairment type without "contamination" from other impairment types. For example, a tapping test for coordination should require minimal range of movement, balance and strength in order to be executed. As far as possible, the test should also exclude the impact of non-eligible impairment types, such as problems with motor planning;
- Account for greatest variance in wheelchair racing performance: within the constraints implied by the first criterion, a given test of impairment should account the maximum possible amount of variance in performance by:
- Assessing the body structures that will impact performance (e.g., elbow ROM will impact wheelchair racing; ankle ROM will not);
- Assessing in body positions relevant to sports performance (e.g., in tests of impaired coordination for wheelchair racing, participants should be tested in a seated position, and movements of the arm should be in the sagittal plane;
- Using composite measures wherever possible (e.g. instead of individually measuring strength at the wrist, elbow and shoulder, a wall-push test involving all of the relevant muscle groups would be likely to produce a measure that would account for more of the variance in wheelchair performance) ;
- Where possible the measure should be resistant to training. For example, in the sport of athletics many athletes use plyometric and power training drills to enhance performance. Therefore if strength impairment was assessed using a plyometric or power measure, it is likely that a well-trained athlete would perform better than untrained athlete of comparable impairment severity, creating the possibility that the well-trained athlete would be placed in a class for athletes with less severe impairments. Isometric strength is not usually trained by athletes and evidence indicates that isometric measures do not respond to power-type training [18], making it a more suitable measure of strength impairment for the purposes of classification in Paralympic athletics.
- Measurement of activity limitation: methods for evaluating activity limitation will vary according to the sport of interest and the impairment group of interest – biomechanical impairment, vision impairment or intellectual impairment. One approach is to identify the vision, intellectual or biomechanical activities that have the greatest impact on performance in the sport of interest, and use these activities as the basis for the development of highly standardised, sport-specific activity limitation test protocols. For example, in order to push a racing wheelchair rapidly requires two biomechanically distinct activities or techniques – the

technique used to accelerate from a stationary position and the technique used to maintain top speed. When athletes with eligible biomechanical impairments (e.g., impaired strength, impaired range of movement or hypertonia) perform these activities – acceleration from stationary and maintenance of top speed – to the best of their ability, then decreasing performance (measured in seconds) will directly reflect increasing activity limitation in wheelchair racing. In order to evaluate the impact of impairment on a sports activity, researchers must ensure that all athletes perform exactly the same, highly standardised activity (i.e., same equipment, positioning etc): if athletes are permitted to adopt individualised positioning and use strapping and other aids, the activity is effectively changed to a new activity in which the impact of impairment is reduced, making comparison of results across participants impossible.

When appropriate measures have been developed, researchers can acquire measures of impairment and performance from a sample of athletes and analyse the results using appropriate multivariate statistics. The result of the multivariate analysis will be a regression equation that reflects the relative strength of association between the various measures of impairment and activity limitation. The sample of athletes upon which the regression equation is based should be racially representative and as large as practical.

Once a regression equation has been derived and verified through research, it will form the basis of classification process. Classifiers will evaluate athletes using the standardised measures of impairment validated through research, and results from each impairment measure will be entered into the relevant regression equation to obtain a single impairment score. The impairment score will have a relationship to activity limitation in the sport of interest that is based upon empirical evidence. In this way the current problems associated with weighting and aggregating measures of impairment will be addressed.

Note that the research methods described above quantify the relative impact of impairment on highly standardised activities that permit very minimal variation in terms of individualised positioning and equipment, and that classification methods that will be used in practice will be based on the relative impact of different impairments on performance of these activities. In the competitive arena, many sports permit classified athletes to use individualised positioning and techniques, as well as strapping and other aids, which effectively alter the activity that each individual does in a way that minimises the impact of an individual's impairment, thereby enhancing performance. Use of individualised adaptations should not affect the class that an

athlete is allocated. However sports technical officials must be cognisant of the impact that each individualised adaption will have and ensure that technical rules governing permissible techniques and aids (including the materials that aids are made of) regulate their use so that the integrity of the sport is maintained.

Dividing impairments into classes

The task of creating classes can be addressed once the relationship between impairment and activity limitation in a given sport has been described. In some instances the data may indicate "natural" classes.[2] Natural classes may be indicated by a single, empirically verifiable critical feature. For example, in lower limb amputees, amputation above the knee causes significantly greater activity limitation in running than amputation below the knee, indicating that athletes with a knee joint should compete in a different class to those without a knee joint. Natural classes may also be indicated where the data indicate a clear cut point in a continuous variable. Figure 3 illustrates the presence of two cut points in a hypothetical data set which plots wheelchair racing performance (y-axis) against wheelchair specific impairment (x-axis), a single, continuous score derived from a number of measures of impairment that have been weighted and aggregated according to an evidence-based regression equation. The graph indicates that decreasing impairment score is associated with improved racing performance (i.e. decreased activity limitation), however the decline is not uniform – a decrease in impairment from ten to eight is associated with a decrease in race time from 100 sec to 90 sec, however an decrease in impairment from eight to seven is associated with a decrease of 30 sec in race time. A similar drop occurs when impairment increases from five to four. These data suggest two cut points and therefore three natural classes: class one for athletes with impairment scores from ten to eight; class two for impairment scores from seven to five and class three for impairment scores from four to one.

In instances when the relationship is strictly linear and does not suggest natural classes, setting the boundaries of classes will be more challenging. Because extent of activity limitation is a continuous variable, it is mathematically impossible to create a classification system in which classes only comprise athletes experiencing exactly the same degree of activity limitation. Given that classes must always span a range of activity limitation, the most important guiding principle for setting the number of classes should be that within any given class, the range of activity limitation should never be so large that athletes with impairments causing the greatest activity limitation are significantly disadvantaged when competing against those with impairments causing the least activity limitation.[4] For example, tetraplegic and paraplegic athletes should

not compete in the same wheelchair racing class because the range of activity limitation resulting from impairment in such a class would be too large. However, to ensure the competitive field for each class is as large as possible, the range of activity limitation within a class should also be as large as possible without disadvantaging those most severely impaired.

It is critical that the number of classes in a given sport is based on these objective principles. When the number of classes has been determined, it is the role of sports federations and their administrators to put in place effective promotion and retention strategies in order to maximise participation and ensure large, competitive fields in each class. If numbers in a particular class are low, this is an indication that a sport needs to employ more effective promotion and retention strategies: it is not an indication that the number of classes should be reduced. The notion that the number of classes in a given sport should be driven by the number of athletes competing in that sport at a single time point will lead to long-term instability in classification systems and runs counter to the aim of developing evidence-based systems of classification.

Other research needs

As has been identified, there is a critical need for research which will describe the extent to which impairments of varying type, severity and distribution impact on performance in the Paralympic sports. However measurement of impairment for the purposes of Paralympic classification poses at least two further significant challenges.

Identifying intentional misrepresentation of abilities

It is well recognised in order to obtain valid measures, many tests of impairment require the athlete to attempt the test to the best of their ability. Anecdotal evidence indicates that some athletes try to obtain a more favourable classification by intentionally misrepresenting their abilities (i.e., not attempting all tests to the best of their ability in order to appear to exaggerate the severity of the impairment). To deter athletes and support staff from conspiring to intentionally misrepresent abilities, the Classification Code [17] contains severe sanctions, up to and including a lifetime ban from Paralympic sport. Objective methods for identifying intentional misrepresentation of abilities would provide an important, empirical basis for enforcing sanctions, and research developing and validating such methods is required. Such methods are an important means of assuring all Paralympic stakeholders – athletes, coaches, administrators, the public and the media – that the fairness and integrity of Paralympic competition is protected by sanctions that are both severe and enforceable.

Training responsiveness of impairment measures

Although measures of impairment will be largely training resistant, they are not entirely. For example, strength impairment resulting from incomplete spinal cord injury can be influenced by behaviour: chronic disuse can compound strength loss in affected muscles, and strength can be increased through resistance training. It is vital that athletes who have positively influenced their impairment scores by training are not competitively disadvantaged by being placed into a less impaired class.

One important means of guarding against this possibility is to use modalities of impairment measurement that are not sports specific. For example, measurement of strength using an isometric modality would reflect strength impairment but would also be more resistant to sports-specific strength training than dynamic modalities of strength measurement.[18]

A further safeguard will be the development of activity limitation test batteries which can be used by classifiers to differentiate untrained from well-trained athletes. These batteries should comprise the activity of interest – for example, a 30m sprint performance for runners in athletics – as well as supplementary tests of activity limitation [19]. The standing broad jump is a good example of a supplementary test of activity limitation for running, because it: a) highlights the impact of one of the eligible impairment types for running (impaired muscle strength); b) is biomechanically distinct from the activity of interest (running), but is closely correlated with running performance[20]; and c) is inexpensive and easily administered, which would facilitate international dissemination and implementation. Valid, reliable tests of activity limitation can provide classifiers with an objective indication of an athlete's level of training which is, as far as possible, independent of the effects of impairment[19] – that is, for a given impairment level, a well-trained athlete will do better on supplementary tests of activity limitation than an untrained athlete. In this way supplementary tests of activity limitation can be used to ensure that well trained athletes are not competitively disadvantaged by Paralympic classification methods.

Glossary

The ICF: the ICF is the acronym for the International Classification of Functioning Disability and Health (ICF), published in 2001 by the World Health Organisation.[21] The ICF is an international standard for describing the functioning and disability associated with health

Health Conditions are diseases, disorders and injuries and are classified in the ICD-10[22], not the ICF. Cerebral palsy, Spina bifida and multiple sclerosis are examples of health conditions;

Body functions are the physiological functions of body systems (e.g., cardiovascular functions and sensory functions). The body functions of central concern in Paralympic sport are visual function, intellectual function and neuromusculoskeletal function (see Figure 1);

Body structures are anatomical parts of the body such as organs and limbs and their components. The body structures of central concern in Paralympic sport are those related to movement and include the motor centers of the brain and spinal cord, as well as the upper and lower limbs (see Figure 1);

Impairments are problems with body functions or body structures. A person with a contracture at the right elbow would be described as having impaired range of movement. Paralympic classification systems should specify eligibility in terms of ICF impairment types (e.g., in the sport Judo, the classification system should specify that only vision impairments are classified);

Activity: an activity is the execution of a task or action by an individual. The term activity encompasses all sports specific movement, including running, jumping, throwing, wheelchair pushing, shooting and kicking (see Figure 1);

Activity limitations are difficulties an individual may have in executing an activity. In Paralympic sport activity limitations refer to difficulty executing the sports-specific movements required for a particular sport. Running is a core activity in the sport of athletics and a person who has difficulty running is said to have an activity limitation in running.

Function and disability: In the ICF the terms “function” and “disability” are non-specific umbrella terms that refer to several components of the ICF. For example, function can refer to neurological function (e.g., nerve conduction velocity), the ability to perform an activity (e.g., ability run or jump) or functioning of a person in the community (e.g., to conduct financial affairs

or access health services). To minimise ambiguity the terms functioning and disability should be avoided when describing the purpose and conceptual bases of Paralympic classification;

Handicap: The term “handicap” is not used in the ICF because of its pejorative connotations in English.

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Competing interests

The authors do not have any competing interests with regard to this manuscript.

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‘What is already known on this topic’

Competition in Paralympic sport is based on systems of classification. The recently published IPC Classification Code mandates development of evidence-based systems of classification. Development of such systems is difficult because consensus regarding what constitutes evidence-based classification do not exist and because, to date, classification in Paralympic sport has been largely atheoretical.

‘What this paper adds’

This paper provides a theoretically-grounded overview the scientific principles underpinning classification, as well as an authoritative position on what constitutes evidence-based classification and guidelines for how evidence-based systems can be developed.

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Table 1: Sports governed by the International Paralympic Committee (IPC) and its member federations as at January 2009.

Sports governed by IPC	Sports governed by IPC Member Federations			
	IOSDs		International Federation Sports	
	Sport	Organisation	Sport	Organisation
Alpine skiing (W)	Boccia	CPISRA	Archery	Fédération International de Tir à l'Arc
Athletics	Football 5-a-side	IBSA	Cycling	Union Cycliste Internationale
Ice sledge hockey (W)	Football 7-a-side	CPISRA	Equestrian	International Equestrian Federation
Nordic Skiing (Biathlon & Cross Country Skiing) (W)	Goalball	IBSA	Rowing	International Rowing Federation
Powerlifting	Judo	IBSA	Sailing	International Foundation for Disabled Sailing
Shooting	Wheelchair fencing	IWAS	Table tennis	International Table Tennis Federation
Swimming	Wheelchair rugby	IWAS	Volleyball (sitting)	World Organization for Volleyball for Disabled
Wheelchair dance sport			Wheelchair basketball	International Wheelchair Basketball

				Federation
			Wheelchair tennis	International Tennis Federation
			Wheelchair curling (W)	World Curling Federation

Acronym Key: IOSD (International Organizations of Sport for the Disabled); Cerebral Palsy International Sport and Recreation Association (CPISRA); International Blind Sport Association (IBSA); International Wheelchair and Amputee Sports Federation (IWAS); Winter sport denoted by (W).

Table 2: Previously proposed statements regarding the conceptual basis of Paralympic classification and why they are unsuitable

Conceptual basis	**Problem with this conceptual basis**
Place athletes into classes according to their degree of function	Although function is affected by impairment, a range of other factors also affect how well a person functions. These factors include age, fitness, motivation. A person who is old, unfit and unmotivated will not function as well as when they were young, fit and motivated. Moreover, we know that training affects function – if it did not, then athletes would not train. If athletes was placed into classes according to function, then an athlete who was young, motivated and well trained would be placed in a more functional class than someone who was older, unmotivated and poorly trained. Paralympic systems of classification should ensure that young, well-trained athletes should gain a competitive advantage and therefore classifying athletes

	according to their degree of function is not a suitable conceptual basis for classification in Paralympic sport.
Place athletes into classes according to their degree of performance potential or innate potential	The performance potential or innate potential of an athlete is determined by an array of natural attributes including, but not limited to, impairment. For example in discus, performance potential or innate potential is obviously negatively influenced by impairment strength. However performance potential is enhanced by increased standing height, arm span and increased proportion of type II (fast twitch) muscle fibres. If athletes were classified according to such constructs, then tall athletes with long arms and an ideal muscle fibre composition would compete in higher classes than short, endurance-type athletes. Paralympic classification systems should ensure that athletes with the best combination of natural attributes have a competitive advantage over others, therefore classifying athletes according to their performance potential is not a suitable conceptual basis for classification in Paralympic sport.

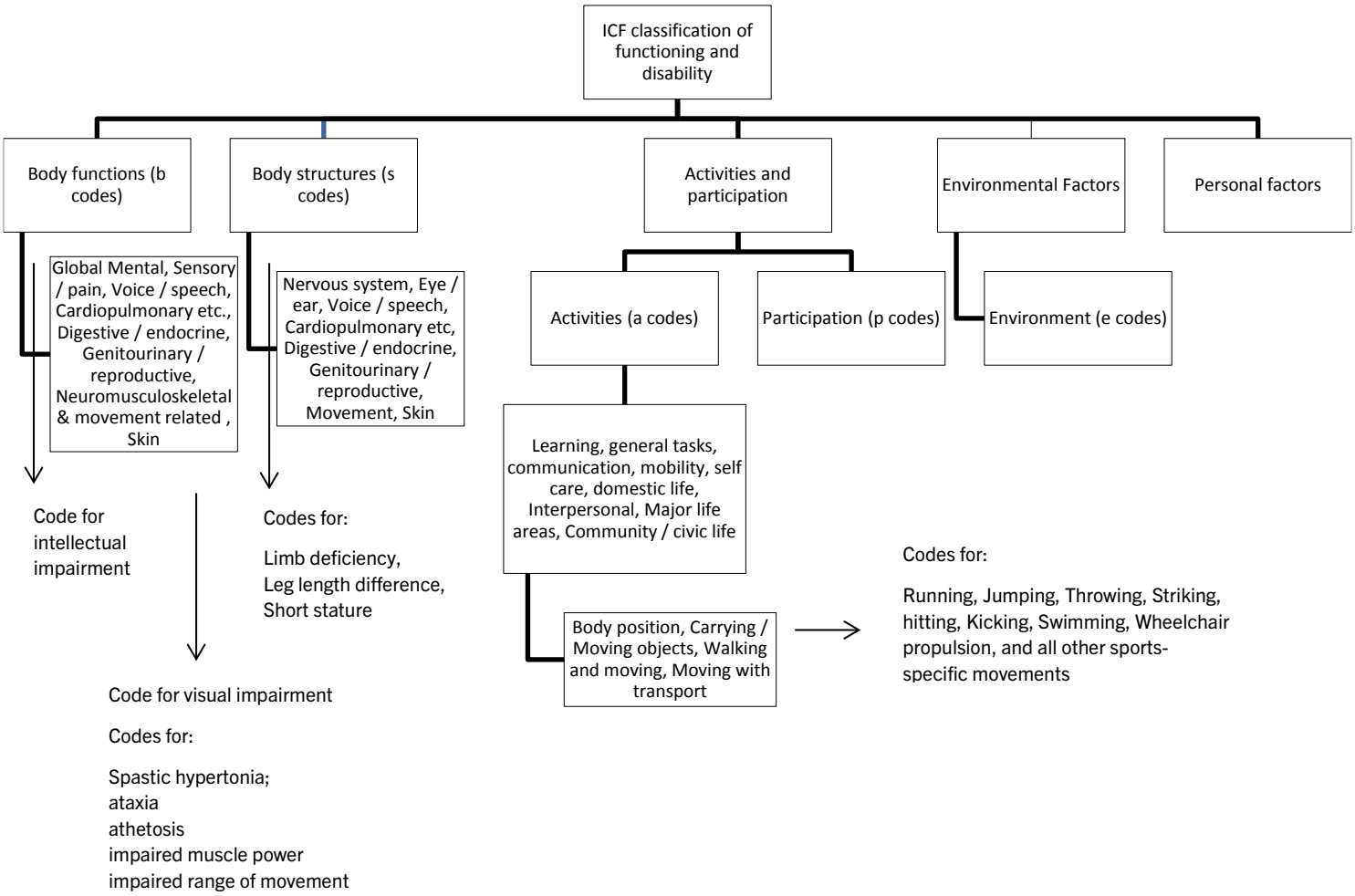

Figure 1: The structure of the International Classification of Functioning Disability and Health with domains of Paralympic sport mapped

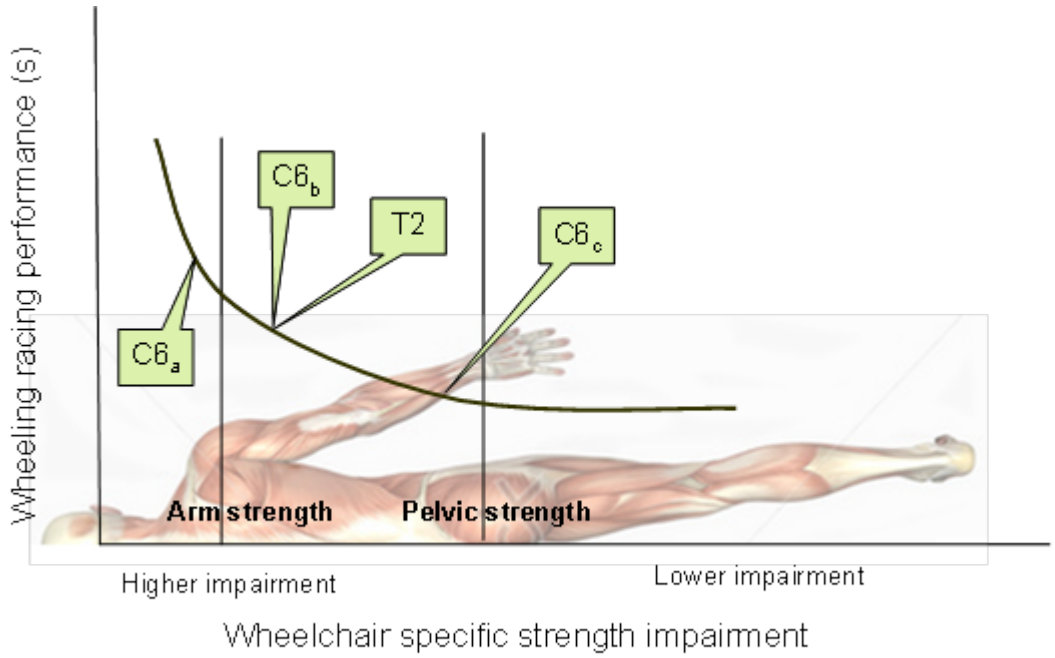

Figure 2: Hypothetical plot – Wheelchair Racing Performance vs. Wheelchair specific Strength Impairment. The hypothetical strength impairment associated with a complete T2 spinal cord injury is indicated, as are the three relative strength impairment scores associated with a C6 incomplete injury: C6a causing greater impairment than T2; C6b the same; and C6c less.

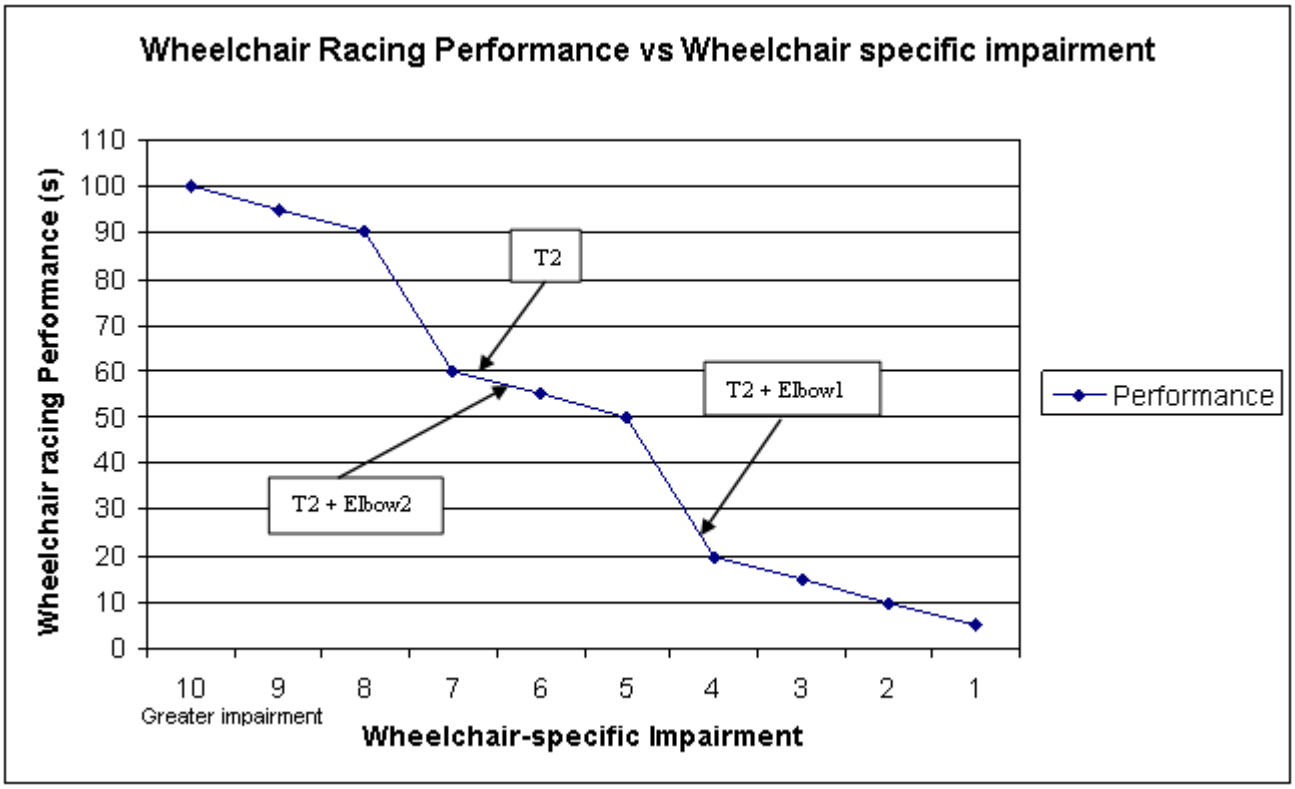

Figure 3: Illustrative graph – Wheelchair racing performance vs. wheelchair-specific impairment. T2 indicates wheelchair specific impairment caused by T2 cord injury with no other impairments; T2 + Elbow1 indicates wheelchair-specific impairment caused by T2 cord injury with elbow extension deficit causing significantly greater activity limitation than T2 injury alone; and T2 + Elbow2 indicates wheelchair-specific impairment caused by T2 injury with elbow extension deficit causing negligible increase in activity limitation.

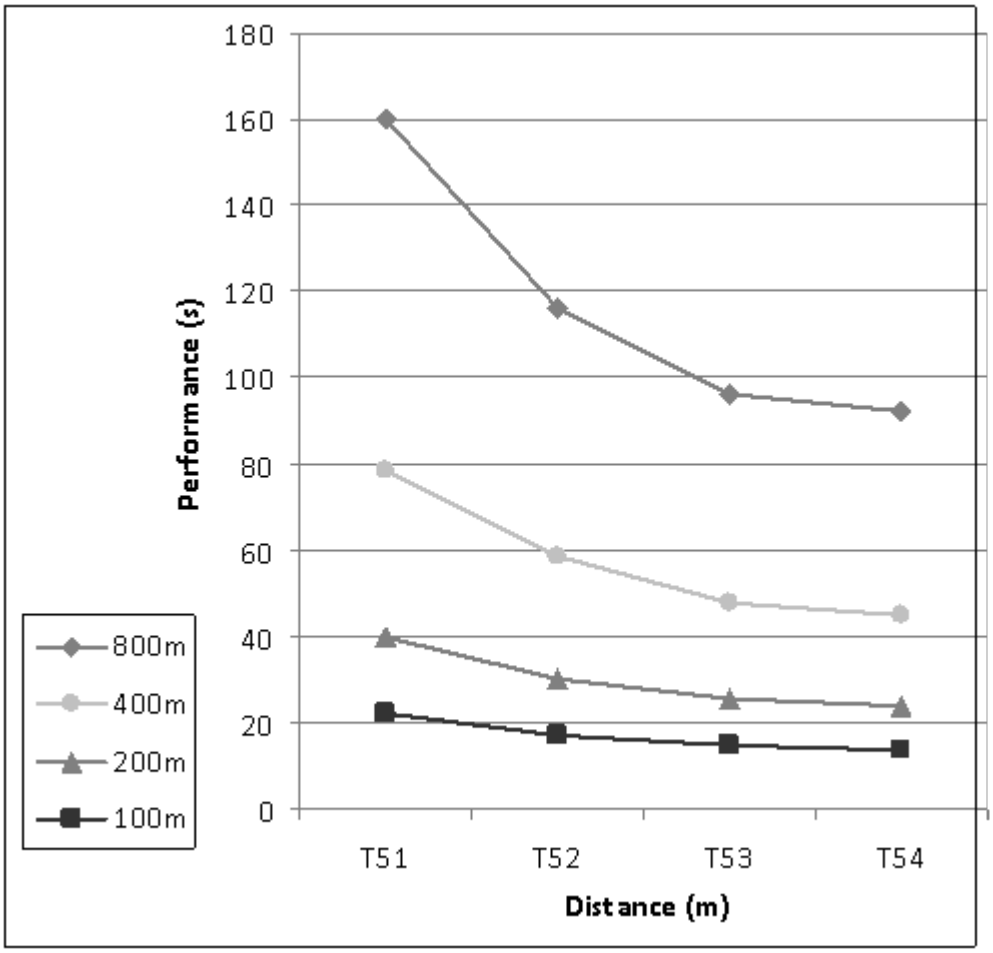

Figure 4: World record times for the four male wheelchair racing classes in para-aAthletics for four distances – 100m, 200m, 400m and 800m