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PAPER



Para-cycling race performance in different sport classes

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ABSTRACT

Purpose: The para-cycling classification system, consisting of five classes (C1–C5) for bicycling (C5 athletes having least impairments), is mostly based on expert-opinion rather than scientific evidence. The aim of this study was to determine the differences in race performance between para-cycling classes.

Methods: From official results of the men's 1 km time trials for classes C1–C5 of seven Union Cycliste Internationale World Championships and Paralympics, median race speed of the five fastest athletes in each class was calculated ($n = 175$). Para-cycling results were expressed as a percentage of able-bodied performance using race results from the same years ($n = 35$). To assess differences between consecutive classes, Kruskal-Wallis tests with Mann-Whitney U post hoc tests were performed, correcting for multiple testing ($p < 0.013$).

Results: Para-cyclists in C1 reached 75% (median \pm interquartile range = 44.8 ± 4.2 km/h) and in C5 90% (53.5 ± 2.9 km/h) of able-bodied race speed (59.4 ± 0.9 km/h). Median race speed between consecutive classes was significantly different ($\chi^2 = 142.6$, $p < 0.01$), except for C4 (52.1 ± 2.8 km/h) and C5 ($U = 447.0$, $p = 0.05$).

Conclusion: Current para-cycling classification does not clearly differentiate between classes with least impairments.

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Para-cycling; paralympic sports; classification; performance; cycling

► IMPLICATIONS FOR REHABILITATION

- The current classification system is not evidence-based and does not clearly differentiate between relevant groups of para-cyclists.
- An evidence-based para-cycling classification system is essential for a fair and equitable competition.
- Fair competition will make it more interesting and increase participation.
- Para-cycling can inspire everyone with and even those without disabilities to be physically active.

Introduction

In para-sports, athletes are classified into sport classes which are based on the degree of physical, visual or cognitive impairment. Classification provides structure to ensure that winning is not determined by the impairment but by the same factors that account for success in able-bodied sports [1]. Classification is sport-specific, as impairments affect performance in different sports to different extents. Para-cycling, which is governed by the International Cycling Federation (Union Cycliste Internationale: UCI), is the third largest Paralympic sport. Para-cyclists with physical impairments compete in three different disciplines: bicycling, tricycling or handcycling. Over the last decade, the sport of para-cycling has grown and today the majority of competing athletes are professional cyclists. However, there is limited scientific evidence for para-cycling classification. The classification system is mostly based on expert opinion whilst the International Paralympic Committee (IPC) has stressed the importance of evidence-based classification [2].

This paper focuses on the discipline of bicycling, which consists of five classes, ranging from C1 to C5 where C1 consists of athletes that have the greatest impairment [3]. A typical race bicycle is used in the C-classes, and depending on the athlete's

impairment, adaptations can be used. Eligible impairments for the C-classes are limb deficiency (e.g., amputations), leg length difference, strength or range of motion impairments, or coordination impairments including hypertonía, ataxia and athetosis. The minimum impairment criteria define how severe the impairment must be to be deemed eligible for para-sports, as described by IPC [4]. In para-cycling, the minimum eligible impairments are defined as amputation of all fingers and thumb (through the metacarpal phalangeal joints) or amputation of more than half of the forefoot, and for leg length difference a minimum of 7 cm difference. For impaired muscle strength and range of motion there are definitions for minimum eligible criteria based on scoring systems using manual muscle testing (MMT) and passive range of motion measurements, respectively [5]. The minimum impairment criteria for coordination impairments are less clearly defined.

In 2010, the classification system changed from being divided into impairment type based classes, with athletes with locomotor impairments such as amputations racing in separate classes than athletes with cerebral palsy, to the current function based system that allows for mixed impairments within classes. It is now possible for an athlete with a locomotor impairment to compete against an athlete with a coordination impairment, however, little

is known concerning the effect of different impairments on cycling performance.

In the C-classes, competitions are held in track and road racing. In a valid classification system, one would expect demonstrable differences in race performance between different sport classes. No difference in performance between classes could possibly mean that the impairments in these classes affect performance in comparable ways. This information of athlete performance could in future studies be combined with measurements of impairment in a re-evaluation of classes. Previous studies on track cycling race times are limited to investigation of split times in the C-classes, with varying results [6,7]. Lepr te et al. [6] showed that C2 and C3 have similar split times during the 2011 UCI Track World Championships 1 km time trials. Wright [7] showed that the split times of C2 at the Paralympic games in London 2012 differed from C1 and C3, while the C2 class had a slower start, a flatter pacing profile and faster split times in the later part of the race compared to the C1 and C3 classes.

The aim of classification is to group athletes together according to the impairment's effect on performance. Tweedy [8] suggests that classes must be designed by not giving the athlete with the most impairment a disadvantage compared to the athlete with the least impairment in the same class, while at the same time have enough room to include a sufficient amount of athletes to maintain competitiveness within the class. This means that in a valid para-cycling classification system, variations in race speed between successive classes should be equal, as should variability within classes. For top performers, there should ideally be no overlap in race speed between classes.

Since the implementation of the current classification system, systematic comparisons of the most important international events, including all classes, are warranted to get a better insight into the classification system and to guide priorities for future research on the para-cycling classification system. To get a standardized evaluation of the differences in race performance between classes, this study will focus on track race results, as individual time trials on the road have to take weather, wind and course conditions into account, making the comparisons between years and events less reliable.

The objective of this study was to investigate the differences in race performance between para-cycling classes at recent major international competitions, and to compare the results to race performance of able-bodied cyclists.

Material and methods

Study sample

As an indicator of track race performance, results of the men's C1–C5 1 km time trial from the years 2011–2018 were extracted. Public data of five UCI World Championships with a total of 355 para-cyclists participating in the races, and two Paralympic games (2012 and 2016) with 96 participants, were obtained (there was no World Championship held in 2013) [9]. The race results of the top five cyclists in the 1 km time trials for each year were analysed ($n = 175$). For comparison, data from men's able-bodied Track Cycling World Championships from 2011 to 2018 ($n = 35$, excluding the year 2013 to match the data available for para-cycling) were also extracted. As there are insufficient top five race results from women's para-cycling 1 km time trials, due to fewer participants in the women's track races compared to the men's races, this study only included male cyclists.

Data analysis

Median race speed (km/h) with interquartile range (IQR) was calculated from the official race time results of all classes for all included events combined. In order to analyse only top performances, the five fastest results of each class at each event were included. Additionally, the para-cycling results were expressed as a percentage of the median race speed of able-bodied cyclists. Kruskal-Wallis tests with Mann-Whitney *U post hoc* tests were performed to assess differences in median race speed between consecutive classes, correcting for multiple testing by adjusting the significance level to $p < 0.013$ (Bonferroni correction: $0.05/4$) (SPSS, version 25). To assess whether results were not influenced by including results of the same athletes at multiple events, a sensitivity analysis was conducted. The sensitivity analysis was performed by including only the fastest race time result of each athlete participating multiple times, and performing the same statistical tests as in the original analysis to assess whether the results remained the same. The IQR of median race speed of each class and able-bodied athletes were compared and overlap of IQR between consecutive classes visually inspected. Since a selection of the fastest race results of each class were made, outliers were kept in the analysis. All outliers were described and discussed.

Results

Descriptive statistics of the different events are presented in Table 1. Figure 1 presents a box plot summarizing race results of all events per class. Median race speed per class ranged from 44.8 km/h \pm 4.2 in C1 to 53.5 km/h \pm 2.9 in C5. The median race speed for able-bodied cyclists was 59.4 km/h \pm 0.9, of which C1 reached 75.4% and C5 reached 90.1% of able-bodied speed. Comparison between classes showed significant differences between consecutive classes ($\chi^2 = 142.6$, $p < 0.01$), except when comparing race speeds of athletes in C4 and C5, with respective median race speed of 52.1 km/h \pm 2.8 and 53.5 km/h \pm 2.9 ($U = 447.0$, $p = 0.05$).

Thirty-nine athletes ended up in the top five more than once during the analysed time period, with five athletes appearing in the results six times during the seven events. A total of 99 race results were excluded, leaving 76 results from unique athletes in the sensitivity analysis. The results of the sensitivity analysis ($\chi^2 = 60.9$, $p < 0.001$) showed comparable results to the original analysis, with significant differences between consecutive classes except between C4 and C5 that had a median race speed of 52.4 km/h \pm 2.7 and 53.7 km/h \pm 3.0 ($U = 65.0$, $p = 0.13$), respectively.

Table 1. Median race speed (km/h) \pm IQR of top five results for each year of the 1 km track time trial of para-cyclists and able-bodied cyclists.

Year*	Median race speed (km/h) \pm IQR					
	C1	C2	C3	C4	C5	Able-bodied**
2011	43.2 \pm 2.3	45.8 \pm 1.4	49.3 \pm 1.4	51.7 \pm 2.9	52.1 \pm 1.0	58.8 \pm 0.9
2012	45.3 \pm 4.5	47.3 \pm 1.6	50.4 \pm 1.2	51.7 \pm 0.8	53.2 \pm 3.0	59.5 \pm 0.9
2014	44.9 \pm 3.8	47.2 \pm 2.3	52.9 \pm 1.0	54.7 \pm 2.7	56.6 \pm 2.1	59.5 \pm 1.1
2015	44.4 \pm 5.1	46.3 \pm 1.3	50.5 \pm 0.9	52.1 \pm 3.0	53.9 \pm 2.1	59.5 \pm 0.5
2016	44.8 \pm 5.8	47.5 \pm 1.6	49.6 \pm 1.4	51.7 \pm 3.7	54.3 \pm 3.0	58.5 \pm 1.3
2017	43.3 \pm 2.8	46.2 \pm 1.3	50.3 \pm 1.3	52.0 \pm 3.2	52.9 \pm 3.4	59.0 \pm 0.3
2018	47.1 \pm 4.3	47.6 \pm 1.6	50.8 \pm 0.6	52.4 \pm 2.7	53.5 \pm 2.4	60.0 \pm 0.8

*2011 World championships in Montichiari, 2012 Paralympic games in London, 2014 World championships in Aquascalientes, 2015 World championships in Apeldoorn, 2016 Paralympic games in Rio de Janeiro, 2017 World championships in Los Angeles, 2018 World championships in Rio de Janeiro.

**2011 World championships in Apeldoorn, 2012 World championships in Melbourne, 2014 World championships in Cali, 2015 World championships in Montigny-le Bretonneux, 2016 World championships in London, 2017 World championships in Hong Kong, 2018 World championships in Apeldoorn.

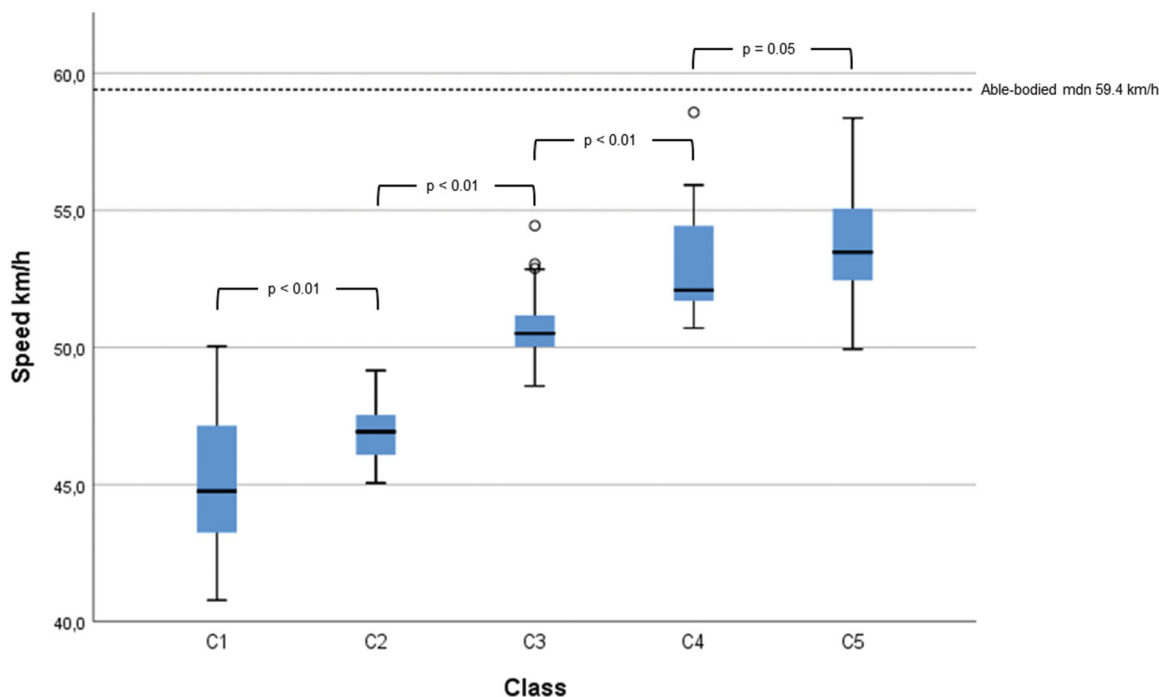


Figure 1. Median race speed (km/h) of the 1 km track time trial per class. Dashed line represents the median race speed of able-bodied.

The IQR of median race speed was largest for C1 (4.1 km/h), and larger in C4 and C5 (2.8 and 2.9 km/h respectively) compared to C2 and C3 (1.5 and 1.3 km/h respectively). Compared to able-bodied athletes (0.9 km/h), IQR was larger in all para-cycling classes. Visual inspection (Figure 1) demonstrates overlap of IQR between C1–C2 and C4–C5.

In total there were four outliers with faster race results than the rest, of which one in the C4 class and three in the C3 class. These four outliers were all from the same event, which was a year (2014) with faster median race speeds for three of the classes (C3–C5) (Table 1).

Discussion

The differences in race performance between para-cyclists racing in C1–C5 classes (C1 greatest impairments) showed that each adjacent class, except for C4 and C5, presented statistically significant differences in average time trial speed, when analysing data from major international track competitions. The limited difference in race performance between C4 and C5 was confirmed by an overlap in ranges of speed between these classes. Overlap of the ranges in race speed were also found between C1 and C2, with C1 showing the largest variation of all sport classes, which was four times larger than the variation in able-bodied athletes. However, it seems unrealistic to strive for equal variances in para-cycling compared to able-bodied cycling as there is such a large range of impairments, which creates a larger variation in performance. The C3 class showed the smallest variation, which requires further investigation taking into account impairment types.

The eligible impairment types for a certain para-sport must impact on sports performance [2]. Therefore, the impairment types eligible for para-cycling need to impact on the physical demands to perform in cycling [4]. The difference in race speed between elite para-cyclists and able-bodied cyclists found in this study, confirms that the criteria that impairments impact cycling performance are met. Similarly to the comparison of race performance between classes in para-swimming [10], the differences between race

performances in classes with athletes with less impairments in this study were smaller than between classes with athletes with greater impairments. Two possible explanations might be the classification system lacking the ability to distinguish between the impacts of impairments on cycling in regard to less impaired athletes, or that athletes with greater impairments need more assistance and effort for training, resulting in larger variation of training volume and therefore more variability in race results. A strength of the current study is that only the fastest five race results of major international events were included, and it is therefore less likely that these results are affected by training status as all participants are top performing athletes. However, a limitation of this study is that the impairment types have not been taken into consideration when analysing the race results. Further research should focus on explaining the variability within and between classes.

The current para-cycling classification system was implemented in 2010, with mixed classes consisting of athletes with a wide range of impairment types. However, the scales currently used to assess coordination might not be comparable to the scales currently used to assess muscle strength [8]. This means that further research is required to justify that athletes with different impairment types compete against each other, by analysing how different impairments impact performance and how they compare.

Very little is known about the impact of different impairments on cycling performance because the majority of research in persons with physical impairments has been performed in a sedentary or inactive population [11–13]. Further research on elite para-cyclists is therefore warranted, as they might have a different physiology from untrained individuals with impairments [14,15]. Additionally, this study only included male cyclists due to the smaller amount of participants in women's para-cycling races, resulting in insufficient race data to fairly evaluate race performance. Further studies are needed to confirm whether these results also apply to women's para-cycling.

Currently there is one para-cycling classification system for both track and road races. These two disciplines however have large differences in terms of race distance, type of bike used and required

skills. During a track race, it is important to be able to stand out of the saddle in the beginning of the race to accelerate quickly, which is not possible for example for athletes in the C2 class with an above knee amputation without a prosthesis, which has been described in a previous study on time trial results [7]. How this compares to a road race has not yet been studied. Many of the para-cyclists compete in both track and road races, and further research should compare the impact of different impairments of performances on both the track and the road and evaluate whether two separate classification systems may be warranted.

Although a velodrome track is generally a standardized race environment, there can still be variations in race performance dependent on the velodrome. In fact, the outliers shown in the results for the C3 and C4 classes are all results from the Bicentennial Velodrome in Mexico that was the venue for the 2014 Para-cycling Track World Championship, which is one of the fastest velodromes in the world because of its high altitude and high humidity which both improve aerodynamics. This track holds many world records in both able-bodied cycling and para-cycling. All athletes had the advantage of accomplishing fast race results at this specific event, and therefore the results were kept in the analysis in this study.

As there is limited scientific evidence supporting the current classification system, classifiers might sometimes be forced to use race results to confirm or correct the class allocated to an athlete. For example, MMT for assessing strength and the scales used for assessing coordination (Australian Spasticity Assessment Scale, Unified Dystonia Rating Scale, Dyskinesia Impairment scale, Scale for the Assessment and Rating of Ataxia) have not been validated for para-cycling classification. MMT has been suggested to have limited use in classification as it is ordinal-scaled [1,16–18]. In general, a valid assessment of coordination impairments is also one of the more challenging aspects in other para-sport classification systems [19,20]. Using race performance to confirm or correct class allocation could create differences between classes that do not necessarily mirror the degree of impairment. Should this be the case, the results of the current study might be biased, making the present para-cycling classification system appear more valid than it is.

In conclusion, limited differences in track time trial performance between the least impaired classes (C4–C5), and overlap in the range of performance between the most impaired (C1–C2) and least impaired classes (C4–C5), indicate that the current classification system does not clearly differentiate between relevant groups of para-cyclists. Further research is warranted to evaluate the impact of different impairments on cycling performance in elite para-cyclists, which will assist in developing an evidence-based classification system.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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