A comparison of the pacing profiles of male runners in the Comrades Marathon “up” run

By

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LIST OF ABBREVIATIONS

CL	Confidence levels
GCP	Good clinical practice
GLMM	Generalised Linear Mixed Effects Model
HREC	Human research ethics committee
km	Kilometres
POPI	Protection of personal information
ROF	Rating of perceived fatigue
RPE	Rating of perceived exertion
SE	Standard error
UCT	University of Cape Town
VO_{2max}	Maximal oxygen uptake
AFT	Advanced Foot Technology

GLOSSARY OF TERMS

Running endurance:	Running many kilometres over an extended time period using aerobic metabolism (1).
Herd mentality:	Runners run as a pack and the pace is dictated by the front runners (2).
End spurt:	An acceleration in speed in the final segment of the race (3).
Pacing profile:	The distribution of energy and work throughout an activity (2, 4).
Marathon:	A running race that covers a distance of 42.2km (2).
Ultramarathon:	A running race that covers a distance further than 42.2km (2).

ABSTRACT

Introduction

Ultramarathon running is gaining popularity worldwide. Due to the difficulty in completing an ultramarathon, knowledge of the most effective pacing to adopt in an ultramarathon race would be invaluable to coaches and runners, as well as of academic interest, since this information is already well established for the standard marathon. The Comrades Marathon is a globally recognised ultramarathon that takes place in South African annually. Its history and difficult undulating route attracts runners of all abilities, from around the world. Adopting the most effective pacing strategy to complete the Comrades Marathon would optimise the performance of a runner and thereby lead to each being more likely to achieve their specific goal.

Aims and Objectives

The aim of this study was to analyse the race results of three years of the Comrades Marathon "up" runs, namely 2015, 2017 and 2019 and to compare the pacing profiles of the fastest through to the slowest male runners in the field. The objectives of this study were 1.) To analyse the race results of the Comrades Marathon "up" run to identify the pacing profiles adopted by the fastest male runners, through to the slower runners; 2.) To compare the pacing profile of the top 10 male runners in each year, relative to their most recent standard marathon pace.

Methods

The study utilised a retrospective design. The study sample included the Comrades Marathon race results over three years of consecutive "up" runs. Only male runners, irrespective of age, were included in the study. If runners featured in more than one race, only their fastest finish time was included in the sample for statistical analysis. Runners were excluded from the study if there were split (intermediate) times missing or if their data was incomplete in some way. In the second part of the study, runners in the top 10 were excluded if their most recent standard marathon time could not be established.

Results

A total of 22 199 male runners were included for data analysis. The data was divided into quartiles, based on finishing time. This resulted in four groups, separated by 1.67-hour intervals. The first group contained the smallest number of participants (n=503) which was only

2.3% of the field and the last quartile (group) contained the most runners at 50.3% of the field (n= 11181).

There was a significant difference between groups one, two, and four in the pacing profile when speed through the race segments was normalised to the speed at which the first segment was run. This was also the case when speed through each segment was normalised to mean race pace (of the entire race). All four groups showed a parabolic pacing profile; specifically, a reverse “J“-shaped, when race pace was normalised to both mean race speed and to speed of the first segment.

Analysis of the elite runners (top 10) for each year, showed that these runners started at an average of 88% of their marathon pace and averaged 80-90% of their marathon pace throughout the race. The elite runners showed a positive pacing profile with moderate effect.

Conclusion

This study showed that there is no significant difference between the pacing profiles of the faster male runners versus slower male runners. Runners adopted a reverse “J”-shaped pacing profile when their pace at different points in the race was compared relative to their mean race pace, or when each segment was compared to the pace in the first segment of the race. This finding is similar to previous studies that found that the most efficient pacing profile in recreational ultramarathon and marathon runners is a parabolic shaped profile.

The elite runners’ Comrades Marathon started the race at an average of 88% of their marathon pace and maintained an average pace of 80-90% of their standard marathon pace, throughout the race.

CHAPTER 1: Introduction and Scope of the Dissertation

1.1 Introduction

Participation in running events exceeding the standard marathon distance is gaining popularity worldwide (5-7). The Ultramarathon distance presents diverse challenges because of the extreme distances and often hilly terrain (6). Typical ultramarathon distances vary from 50km to 161km and can take place over several days, with the terrain consisting of either tar roads or trail (6, 7). South Africa hosts two globally recognised ultramarathon races known as the Two Oceans Ultra Marathon (56km) and the Comrades Marathon (87- 91km), which attract runners of all ages and calibre (8).

Both elite and "club" runners train consistently for months leading up to these races, but performance on the day can be influenced by many factors, one being the speed at which the runner starts the race, followed by the speed run over different sections of the course i.e. the pacing profile employed. How a runner paces themselves influences their energy expenditure and development of peripheral fatigue (5, 9, 10). Thus, adopting the most effective pacing profile for a specific distance or event can optimise the performance of a runner and contribute to achieving their specific goal; conversely, a poor approach to pacing in a race can result in not achieving a time that might be physiologically possible.

Pacing during a race is dependent on the sum of many factors, including the runner's experience, race goal, the behaviour of their competitors and the route terrain and environmental conditions (5, 11, 12). Effective pacing consists of continuous decision making throughout the race. Strategic decisions are made before the race, however, during the race tactical decisions are made in response to the behaviour of rivals and changes in physiological or psychological status (13). There are various types of pacing profiles described in the literature, namely positive pacing, negative pacing, even pacing and parabolic- shaped pacing (including "U"-shape, "J"-shape and reverse "J"-shape) (5, 13, 14).

It has been shown that even pacing is the most efficient pacing strategy in marathon running because even minor speed fluctuations can lead to increased energy demand (5). However, most studies performed on the standard marathon distance are mostly on "flat and fast" courses (15). The situation in the ultramarathon is more complex, as the terrain, distance and elevation differs substantially between races (16).

The limited studies done on pacing profiles over ultramarathon distances have mostly been done on 100km (up to 161km) trail races, with extreme elevation, or on flat athletics tracks or tarred road routes (10, 17-23). These studies typically have only analysed the race results over one event. Considering that external factors such as heat and humidity could impact the pacing strategies of the runners on race day (18), to determine the pacing profile for an ultramarathon, the pacing profiles used over a number of races i.e. more than just one running of the race, should be assessed, to reduce the influence of years in which the race might have been run under extreme conditions of heat, cold, humidity, wind, etc. To our knowledge, only three studies analysed the pacing profiles of runners over three or more consecutive years, and these were performed on Ultra-trail du Mont Blanc from 2017-2021 (trail run) (24), 100km road run Lauf Biel in Switzerland between 2000-2009 (a circular road route with a total elevation of 645m) (22), and the International Ultramarathon Festival 24hr race in Greece (2011 until 2020) (asphalt running track) (25).

The Comrades Marathon is an example of an ultramarathon road race which has an undulating profile. It is a world renowned race that has attracted thousands of runners (elite and club level) and spectators every year (26). This unique ultramarathon is run in two directions, between two cities, which alternates direction every year. The "up" run takes place from Durban to Pietermaritzburg and the "down" run from Pietermaritzburg to Durban. In 2019, Gerda Steyn, from South Africa, broke Frith van der Merwe's long standing record for the "up" run, in a time of 5:58:39 (hh:mm:ss) (27). Van der Merwe also held the women's record for the "down" run since 1989, with a time of 5:54:43, which Gerda Steyn obliterated in 2023, with a time of 5:44:56 (28). However, the latter was on a somewhat shorter course, but even so, if pace per km is calculated, Steyn is still faster and now holds the "down" run record. Leonid Shvetsov is the current men's record holder for the "up" run, with a time of 5:24:39 and Tete Dijana holds the record for the "down" run, with a time of 5:13:58 (27) . Records aside, most of the runners finish the race between 11 and 12 hours, striving to make the cut off of 12 hours and to receive a finishers medal (26, 29).

To the best of our knowledge, performance and pacing strategies of both elite and recreational runners participating in the Comrades Marathon, have not been investigated. Thus, the aim of the study was to establish pacing patterns of the male runners participating in the Comrades Marathon "up" run and to determine if there is a difference in pacing profiles adopted by the faster male runners compared to the slower male runners in the Comrades Marathon.

1.2 Aims and Objectives

1.2.1 Aim

This study aimed to compare the pacing profiles of male runners, from the fastest 25% through to the slowest 25% in the Comrades Marathon "up" run using pooled results of the 2015, 2017 and 2019 races.

1.2.2 Objectives

The specific objectives of the study are:

1) To analyse the race results of the Comrades Marathon “up” run to identify the pacing profiles of the fastest male runners, through to the slowest male runners in the field.
2) To compare how the elite runners (top 10 male runners’) in each year, pace in the Comrades Marathon “up” run relative to their most recent marathon time.

1.3 Significance of the Dissertation

There is limited available literature on the pacing profiles adopted by ultramarathon runners, specifically road running events. The Comrades Marathon that takes place in South Africa annually, is one of the most prestigious of all ultramarathon events. Coaches and ultramarathon runners of all ability strive to improve running performance in the event; knowledge of the most effective pacing strategies would be valuable in the quest to enhance performance, whether it be to set a record for the race, improve a runner’s personal best time or just to complete the race within the time limit.

1.4 Plan of Development

To investigate this topic further, a comprehensive review on the literature on pacing strategies in ultramarathon and marathon running events are presented in Chapter Two. This forms the foundation for the retrospective design study, establishing and then comparing the pacing profile of the male runners in the Comrades Marathon “up” run (Chapter 3). Finally, Chapter 4 presents a summary and conclusion of this study, including limitations of the study and suggestions for further research on this topic.

CHAPTER 2: Literature Review

2.1 Introduction

2.1.1 Overview

Ultra-endurance running is increasing in popularity all over the world (24, 30, 31). This endurance obsession has led to many long-distance runners aspiring to compete in distances beyond the standard marathon. South Africa's "ultimate human race", the Comrades Marathon, represents history and tradition and is one of the most sort after ultramarathons in the world for ultramarathoners (32). Whether the runner's goal is to win the event or to simply "tick the box", most strive for optimal performance on race day (9).

Regardless of their capabilities, most runners train consistently for months leading up to these races, but performance on the day can be influenced by the way in which runners pace themselves during the race, which influences how the runner fatigues and how their energy expenditure is regulated (9, 10). Due to modern technology and professional timing companies being used at running events, it is possible to analyse the time data of each runner when they cross the numerous timing check points throughout the race.

2.1.2 Review Methodology

This narrative literature review presents current research on pacing profiles of elite and recreational ultramarathon runners. Five databases were searched: Cochrane Database, EBSCOhost, Google scholar, PubMed, and Scopus. Databases were searched from inception up until 30 August 2023. In each database, the title, abstract and keywords were searched. Search terms used included: *"pacing strategies", "pacing profiles", "run", "running performance", "ultramarathon",* for the sections investigating pacing profiles used in ultramarathons. An additional search was used to investigate the targeted race using the search terms: *"comrades marathon"* and *"run"*. Boolean operates (AND, OR) were used in combination with the keywords. Only those articles for which full text was available was included in this review. Additional relevant articles were individually selected from the reference list in selected articles.

2.2 Background

2.2.1 Background of Ultramarathon Running

The participation in ultramarathon distance has grown exponentially, specifically in the last decade, probably due to the increase in races and the number of age group finishers (33). An ultramarathon is defined as a running race or event that is further than 42.2km (34). Ultramarathon races range from 50km in distance to 100 miles and more, to multistage road or trail runs, and are also events measured by duration (i.e. 12-24 hours race) (33). Male runners, at an average age of 45 years, dominate the participation field in the Comrades Marathon and other ultramarathons, whereas women only represent about 20% of the total number of finishers (24, 33, 35). The age of peak performance for ultramarathons appears to increase as the distances increases. In 50km ultramarathons, the average age of best performance is 30-40 years, increasing to 30-39 years in males and 40-49 years for females in 161km (100 mile) events (33).

Runners generally progress from first running several marathons before progressing to ultramarathons (33, 34, 36). Waskiewicz et al. (36) examined the motivation of ultramarathon finishers and those who have not completed an ultramarathon. They used the Motivation of Marathoners Scale (MOMS) and found that shorter distance runners are internally motivated by health or goal setting (34), whereas successful ultramarathon runners are generally internally motivated by affiliation and “life meaning” and the adventure that ultramarathons offers (33, 36). Additionally, elite runners could be motivated by improving their performance, and the potential to win prize money or break a record (33).

2.2.1.1 The Comrades Marathon

The Comrades Marathon has the longest standing tradition in the world in the realm of ultra-running and hosts a wide calibre of runners (37, 38). To participate in the “Comrades”, runners need to qualify by running under five hours for a marathon within the same season (29). What makes this road race different to other ultramarathons, is that the direction of the race alternates every year (37, 39).

The route

The run from Durban to Pietermaritzburg is predominantly uphill in elevation and thus is known as the “up” run and is approximately 87km in length (Figure 2.1) (32, 37, 39). The “down” run, from Pietermaritzburg to Durban, is predominantly downhill, and approximately 89km long (Figure 2.2) (37). The road route offers a challenging undulating profile and as a result, the pacing pattern over the flatter sections of the route might differ from the hillier sections, and it could be expected that some runners might excel in one direction rather than the other (32, 39).

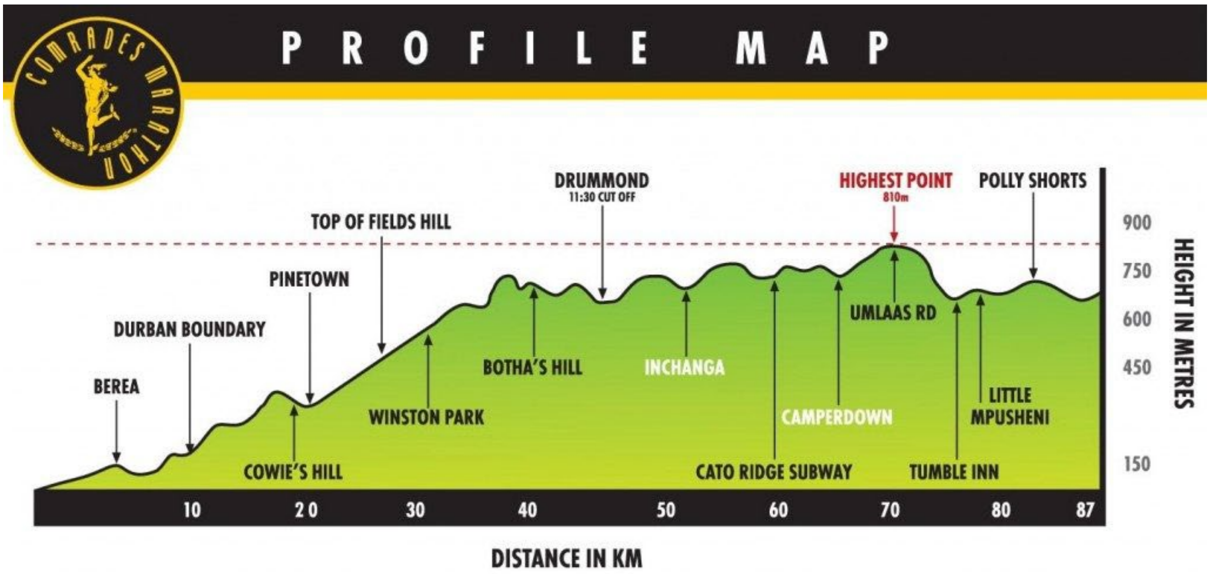

Figure 2.1 The route profile of the Comrades Marathon "Up run" from Durban to Pietermaritzburg.

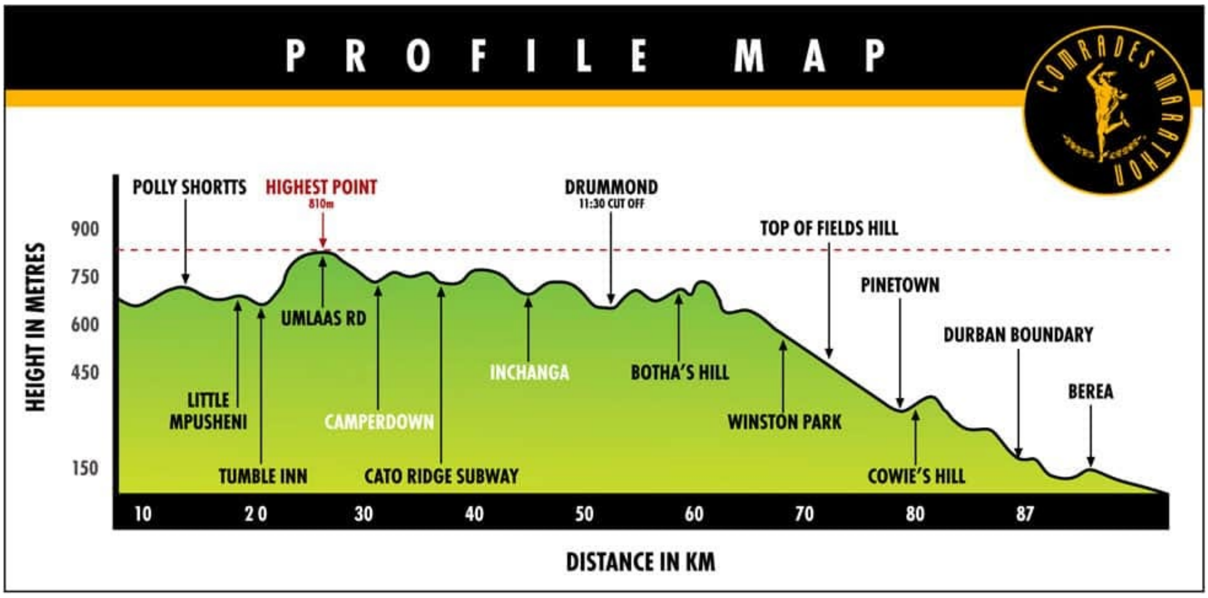

Figure 2.2 The route profile of the Comrades Marathon "Down run" from Pietermaritzburg to Durban.

The Medals

This race offers numerous accolades for runners of different calibre and is possibly the motivation for recreational runners to challenge themselves by running this race. Medals are currently awarded for different achievements in the Comrades Marathon. One popular medal, which is contributing to the growing interest in this race, is the "back-to-back" medal, awarded to runners who complete their first and second races (up and down run) in succession (29). Prior to the year 2000, only three categories of medal were awarded: gold, silver and bronze (29). Currently, there are eight medals which are achieved based on an individual's performance. The additional five medals were introduced since 2001 (29). The first of these is the Wally Haywood medal which was named after Wally Hayward who won the comrades five times (29), and is awarded to the male runners who finish outside of the top 10, but still finish the race within six hours. The Bill Rowan medal was named after the first runner to win the Comrades Marathon (in 1921), in a time of 8hrs 59min and thus inspired the time limit of the medal (29, 32). The "finishers" medal is awarded to runners who finish the race within the last hour of the race until the cut off time of 12 hours. It is named after the race founder, Vic Clapman, who introduced the medal in 2003, when the time limit to complete the race was extended by an hour, to 12 hours (29, 32). Table 2.1 highlights the medal classification.

Table 2.2 Comrades Marathon medal classifications

Medal	**Criteria**
Gold medal	Top 10 Men and Women
Wally Hayward medal	Men only; 11th position to sub 6hrs 00min
Isavel Roche-Kelly medal	Women only; 11th position to sub 7hrs 30min
Silver medal	Men only; 6hrs 00min 01sec to sub 7hrs 30min
Bill Rowan medal	7hrs 30 min to sub 9hrs 00 min
Robert Mtshali medal	9hrs 00 min to 09hrs 59 min
Bronze medal	10hrs 00 min to sub 10hrs 59 min
Vic Clapham medal	11hrs 00 min to sub 11hrs 59 min

2.3 Factors Influencing Running Performance.

2.3.1 Pacing Profiles

Pacing is described as the distribution of a runner's work and effort during an event (2), and it is one of the key factors affecting performance during a race (2, 40). Runners pace themselves in a race based on the duration or distance of the event and the psycho-physiological strain and the perceived difficulties of the race itself (41, 42). Effective pacing during a race can give one competitor an advantage over another (21, 39), but it can also help recreational runners successfully complete a marathon or ultramarathon. There may be very limited physiological differences between the top athletes in these competitions and thus the difference between winning or losing can be due to who can optimize their energy expenditure and prevent premature fatigue before the race ends (40). In addition, selecting the most optimal pacing strategy, can reduce the risk of musculoskeletal injury or increase the overall pleasure of the race experienced by recreational runners (43).

Many research studies have been conducted on pacing profiles over the marathon distance, but less so in the ultramarathon distance. Elite runners maintain a consistent pace during a standard marathon, whereas less experienced runners gradually slow their pace in the second half of the race (10, 40, 44). Similarly, in study on the 1995 100km IAU World Challenge in Netherlands, the top ten runners (elite runners) ran with less variation in pace throughout the race, compared to the slower runners (10). In the past 50 years, the pacing strategy of marathon world record holders has changed from a *positive strategy* (progressively slowing down in the second half of the race) to starting at a more consistent pace and gradually increasing speed after 25km, adopting a *negative pacing profile* (40). In 2022, Eliud Kipchoge from Kenya, adopted an *even paced profile* throughout the Berlin Marathon, to break his own record by 30 seconds (40, 45). However, in 2023, Kelvin Kiptum of Kenya, broke Kipchoge's record at the Chicago Marathon in a time of 2:00:35, where he ran the second half faster than the first half (negative pacing). He ran the first half in a time of 1:00:48 and the second half in a time of 59:47. This leaves some uncertainty as to which pacing profile is indeed more efficient over the marathon distance (40).

Various ultramarathon races have been studied (Table 2.2) (10, 17, 18, 21-23, 46, 47), but due to the variability in distance, route, terrain and elevation and other factors, the findings are inconsistent. Most studies on the pacing profiles of ultramarathon races have been done on events that are on flat courses. These studies show that an increased variability of speed within a race is associated with increased physiological stress and reduced overall power output, thus proving consistent pacing over a long duration to be a more efficient pacing profile (2). The studies that suggest even pacing is the most optimal pacing strategy used in marathon and ultramarathon events, were conducted under stable environmental conditions and limited changes in elevation, and have also been performed on well-trained or elite runners (10-12, 17, 21, 33, 37, 48).

Controlling variability in pace is the most important feature for performance (44). In support of this concept, an analysis of race splits showed that the top 10 runners in a 100km Ultra-marathon race kept their pace more consistent than the rest of the runners finishing between 11th and 77th place (10). Similarly, consistent pacing was shown to be the best pacing profile of the top trail runners in the Mont Blanc ultramarathon trail race (distance of 171km with 10000m of elevation), regardless of gender or age, in the 2008-2019 races (17). This could be due to the of high performance standard of the runners, as a result of the extensive qualification criteria (17). Unfortunately this cannot be generalised for all ultramarathon events as the terrain, distance and elevation changes substantially between each of the races and only 11% of the runners who finished the races were women, and thus results might not be representative of female pacing patterns (17).

Although most studies have been performed on elite and experienced high-performance runners, the majority of marathon and ultramarathon participants are not elite runners and it might be more advantages for them to adopt a "variable" pace (e.g. a run-walk strategy) (48). In addition, the possible reasons for adopting a variable pacing profile could be due to external environmental factors such as wind and temperature and course elevation changes (12). Adopting a planned pacing profile such as run-walk intervals can allow a runner to successfully complete the marathon by limiting the impact of fatigue (48), at the cost of a slower performance. Haney and Mercer (48) reported that non-elite marathon runners had more variability of pace compared to elite marathon runners. Ultimately, selecting an "optimal" pacing strategy is specific to the runner's goal.

Another common type of pacing profile identified in marathon and ultramarathon races is parabolic-shaped pacing, which refers to "U", "J" and reversed "J"-shaped pacing profiles, where runners adopt a combination of positive and negative pacing profiles through the race (12). Ultramaratonia Rio is a 24-hour ultramarathon distance running event that is held on a 400m athletics track in Brazil, with the purpose to run as far as possible in 24 hours (18). Bossi et al. (18) compared the race results for five consecutive years (2008-2012) and found that runners progressively reduced their speed during the race, but then sped up slightly in the final hours, before slowing down in the last hour, reflecting a reverse "J"-shaped pacing profile. The faster runners ran at a more conservative pace in the beginning compared to the slower runners who ran relatively fast compared to their average overall pace (18). It is suggested that the slower runners started too quickly, which resulted in fatigue and thus a reduction in speed towards the finish (18). Alternatively, starting conservatively and reducing the variability in pace favours optimal performance (12). A limitation to this study is that the runners did not all complete 24 hours of running; however, they all completed at least 19 hours due to stopping for nutrition and potentially having a rest. Tan et al. (21) identified similar findings in 101km and 161km races which took place on flat roads. The faster runners showed less variation in pace, whereas the slower runners demonstrated a reverse "J"-shaped pacing profile (21).

Table 2.2 Pacing strategies in ultramarathon races.

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
Bossi et al. (18)	Observational Study	501 well trained runners M: 398 F: 103	Ultramaratonia Rio- 24 hrs race (19.2 hrs (80% total duration) cut off)	400m Track – directional changes every 2hrs.	Hour-by-hour splits and final race results obtained from the website.	Reverse "J"-shaped pacing strategy and decreased speed in last hour	Top runners: conservative pace in the first hours versus the slower runners No correlation between racing time and sex or age (similar pacing strategies)

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
Inoue et al. (47)		51 runners M: 30 F: 21	2013 VI Rio 24h Marines Ultramarathon	On a 400m athletics track	Runners had to complete 50% of the total race distance completed by the winner (male: 214km and female:193.2km)	Reverse "J"-shaped pacing strategy with an end spurt in the last 10% of the race.	
Knechtle (22)	Observational Study	M: Elite runners vs age grouper runners (Top 10 athletes in each division)	100km Lauf Biel, in Switzerland (2000-2009)	1x 100km circular route, total elevation of 645m	Measured changes in run speed over 3 segments in the race.	Top ten athletes slowed across the first two segments but remain constant over the last segment. The youngest age groupers had the largest decrease in pace throughout the race.	Runners run through the night starting at 23:00.

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
Lambert (10)	Observational study	67 runners	1995 100km IAU World Challenge	Flat, 10km loops road	Mean running speed was calculated for each 10km segments in the race	Faster runners had less variability in running speed and started faster than the slower runners and were able to maintain the speed.	
Matta (46)	Descriptive Cohort Study	Race 1: n=16 Race 2: n=10	6h Time trial repeated twice 4 weeks apart	400m track, direction changes every hour	Race 1: Self-paced Race 2: initial 36min at speeds 18% below the mean speed of the initial 36min of race 1	Reversed sigmoid pacing. Slower start reduced RPE and ROF. No change in performance or	Two 6hr runs 4 weeks apart

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
						running kinematics with reducing speed in the first 10% of the race.	
Parise (23)	Cohort study	n= 50 runners M: 42 F:8	161km Trail 2006 (hot year) and 2007 (cold year)	Undulating, varied terrain	Compared average pace of two consecutive years	Faster runners were more negatively affected by hot conditions then slower runners.	
Suter (17)	Observational study	All finishers n=13829 M: 12681 F:1148	171km Ultra trail du Mont Blanc 2008-2019 (Time limit of 46h30min)	Trail 10000m elevation	Observing the results of the races. Measuring the overall pacing	Evan pacing associated with faster average pace regardless of	No difference in performance levels: Runners had a high-performance

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
					across the timing segments	sex. The fastest men were younger than the fastest women.	level required for registration.
Tan et al. (21)	Descriptive field study	Elite vs recreational runners n=47 (161km) n=120 (101km)	161km vs 101km Craze Ultra marathon Singapore 2012 and 2013	Flat road of “out and back’ 50.5km-85km loop	Observing the results of the races. Measuring the overall pacing across the timing segments	Evan Paced strategies in faster runners. Slower runners had more variation in pace. Reversed “J”-shaped Pacing Profile in	Temperatures 32°C and Humidity 65%

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info
						slower runners.	
Chatzakis (25)		Recreational runners n= 283 M 237 F=46	24hr race international ultramarathon festival (2011-2021)	Asphalt flat 1km round loop	Observing the pacing profile relative to the mean pace of the runner's race. Secondly dividing the race into two segments and calculating the distance run at 6h and 12 hours	"J"-shaped pacing profile. Significant difference between pacing and performance standard (increased performance standard showed less variation in pace) but not between pacing and genders.	

Article	Study type	Sample	The race	Route	The protocol	Findings	Additional info

n- number of participants

M - Male

F - Female

RPE – Rating of Perceived Exertion

ROF – Rating of fatigue

2.3.2 Psychological Factors

Running performance in a race can be influenced by psychological factors which affect self-selected pacing and as a consequence, fatigue (12). One of these traits is perceived self-efficacy. How a runner perceives their capability to perform during an event can influence how much effort they put in (49). If an event is associated with increased pain and discomfort, having limited self-efficacy could result in a lower performance or persistence to complete the event, compared to a higher self-efficacy (49). Runners with higher self-efficacy may have higher levels of mental toughness which allows them to push through the pain.

Another psychological factor that influences performance is the runner's rating of perceived exertion (RPE), a subjective measure which relates to how he/she perceives the exercise intensity (running speed) (12). Inexperienced runners start a race at speeds faster than they are capable of maintaining, because they have unrealistic expectations (12, 21) and no innate ability of judging the speed they should be running at, in relation to the race distance. These factors cause premature fatigue *and* then results in the runner slowing down to prevent failure of any physiological system and ultimately reduces performance (12). The findings of Tan et al. (21) discussed above are supported by those of Matta et al. (46). They present data from two 6-hour ultramarathon races, performed for their experiment, that were raced on a 400m athletics track, with the purpose to run as far as possible in 6 hours (46). Participants were instructed to run the first simulated ultramarathon at a self-selected pace. Four weeks later, participants ran the second race around the athletics track, at a specifically slower pace for the first 36 minutes, followed by a self-selected pace for the rest of the 6 hours (46). In the first race, runners who ran the first 30% of the race at high speed progressively reduced their speeds for the next 60% after which they maintained a constant speed until the finish (46). This type of pacing describes an inverse sigmoid pacing profile (46). Consequently, this lead to the runners' RPE and fatigue linearly increasing throughout the duration of the race (46). In comparison, when runners started slower or more conservatively in the second race, they ran faster for between 50% and 90% of the race duration and they reported a lower RPE and reduced fatigue. Despite this, there was no change in performance because the runners ran the same distance in both races (46). This study by Matta (46) had a few limitations which could have related to psychological factors influencing the pacing. Firstly, the limited number of participants (n=16) of the study had to perform both races. The repetitive nature of running for six hours around a 400m athletics track and having to race the same course twice in four weeks, is assumed to reduce motivation, which is likely to also have influenced performance in the second race (46).

A common phenomenon found in most studies investigating pacing profiles is that runners increase their speed in the last 5% of the race, irrespective of race distance, known as an "end spurt" (21). An end spurt is commonly preceded by a decline in pace mid- race which is commonly seen in parabola- shaped pacing profiles (18, 25, 47, 50). It appears that knowing that the end of the race is near, could be the motivation to increase the running pace (18, 21, 41).

Another phenomena observed in endurance racing is that some runners are influenced by the "herd mentality" where runners who are running at a similar pace form packs, with the intent to maintain the speed for as long as possible and select a muscular work rate based on their competitors, while not considering their personal physiological status (12, 18, 21, 41). This influences their pacing strategy and can positively or negatively influence their performance. The positive effect of herd mentality is that the group could enhance the runners' emotions and keep them motivated to maintain the pace of the group. This could influence their self-efficacy and result in the runner achieving a faster finishing time than they thought was possible (51). Alternatively, it could negatively affect performance by causing the runner to run outside of their physiological limit to maintain the speed of the group and result in early fatigue.

2.3.3 Age

The runners' age and experience in the sport (how many races he/she has participated in) and training level may influence the ability to pace efficiently during a marathon (9, 15). This may be significant as the demographic of athletes participating in ultramarathon distances tend to be older than those participating in shorter distances (17, 52). Indeed, the average ultramarathon runner has run for 7.3 years before completing their first ultramarathon (22). The years of running experience before participation in the ultramarathon distance may possibly be a reason why runners over the age of 30 years tend to run more evenly paced throughout a marathon compared to younger runners (10, 17, 22). It is assumed that experience in completing numerous ultramarathon distances and becoming accustomed to pacing strategies in training, in conjunction with running adequate mileage during training, can benefit performance on race day (10).

2.3.4 Environmental Factors

Most ultramarathon races may experience varying conditions throughout the race, due to the extended period it takes to complete the distance. The weather plays an important role physically and psychologically in majority of runners. Some runners prefer running in cooler temperatures, whereas others prefer the heat. Importantly, the humidity, temperature and wind conditions play a role in the hydration status of runners as well as their mental state (9).

Parise and Hoffman (23) examined the effects of hot versus cold temperatures on the runners' ability to pace themselves in the 161km Western States Endurance Run in North America in 2006 and 2007. Conditions in 2006 were hot, with temperatures ranging from 7.2°C to 38°C, humidity from 46% to 56% and wind speed between 2-10km/h. In contrast, in 2007, temperatures were cooler, ranging from 2.2°C to 30.6°C, humidity ranged from 38% to 43% and there was no wind (23). These temperatures were not taken at exact check points in the race but rather from nearby areas, resulting in variations in humidity reported (23). It was concluded that the average pace over the 161km was slower in 2006, by 27-49 seconds per kilometre, suggesting that hotter ambient temperatures during the race negatively affected performance (23). It is Important to note, however, that when comparing the average pace in the early stages of the race in 2006 versus 2007, there was also a reduction in speed of 35 to 45 seconds per kilometre despite the cooler temperatures in the early mornings (23). Thus, it is difficult draw firm conclusions from this study. A limitation to this study was the small sample size (n=50) and selection bias due to only runners who completed both races being included.

Generally, however, it is acknowledged that environmental temperatures of between 30-40°C impair performance. In well trained runners, physiological fatigue is reached at rectal temperatures of approximately 38.7°C, where runners commonly experience symptoms of confusion, dizziness, loss of coordination and syncope (53). It is proposed that the body's central nervous system is directly affected by the high body temperature (53). This central mechanism decreases muscle activation and work rate before body temperature reaches critically high levels and thus impairs self-paced exercise performance (53).

The terrain of the route and elevation gain/ loss in a race can affect the pacing profile for all runners in a marathon or ultramarathon. Optimal running speed is influenced by the gradient of the hills and the amount of energy required to run up and down steep hills (41). Kerherve et al. (41) found that runners who participated on flat road route of 100km had a more even paced profile compared to trail routes, having a reversed "J"-shape or positive pacing strategies (17, 18).

2.3.5 Physiological Factors

The velocity elicited at VO_{2max}, is known as maximal aerobic velocity (vVO_{2max}), and is also considered a performance limiting factor in ultramarathons (54). High performance ultramarathon runners are reliant on a high VO_{2max}, high fraction of VO_{2max} utilization and low cost of oxygen transport (54). Runners utilize on average 65% of VO_{2max} during a 100km race but there is a large variation in resistance to fatigue and running economy (RE) which could be related to varying levels of performance (10). Running economy refers to oxygen uptake at a given submaximal intensity. If a runner's RE is high, they can maintain higher speeds at the same oxygen consumption. Many studies confirm that faster runners, and more experienced runners, pace with less variation in running speed which is said to better maintain physiological homeostasis (22, 25, 37).

In addition, neuromuscular changes could be contributing to fatigue and impaired muscle function due to the repetitive eccentric contractions endured by the muscles, specifically the knee extensors (10, 54). Ultra-endurance events place sheer stress and an increased oxygen demand on the skeletal muscles and heart (54). This causes an increase in pro inflammatory markers and changes in the endothelial function (54). Running downhill is related to potential skeletal muscle damage due to the eccentric muscle contractions involved (2). As a result, some runners might pace cautiously downhill in order to reduce the risk of injury and to maintain performance (2). Uphill ultramarathon running also places a higher load on the body irrespective of age, performance and training status. During uphill running, there is an increase in cardiac and skeletal muscle blood flow injury biomarkers, due to the repeated concentric muscle contractions, and a higher cardiac afterload and vascular resistance (54). However, an increase in cardiac troponin (marker of cardiac damage) does not affect performance (54). Consequently, runners will slow their pace down, or slower runners will walk the up hills to manage their work rate.

2.4 Conclusion

Ultramarathon running is growing exponentially worldwide due to the increase in interest of recreational runners. The literature abounds with studies investigating the pacing strategies of marathon runners, from world record status to recreational runners, but less so in ultramarathons.

Pacing strategy is a key factor determining performance in a race, whether it be to win or to just finish. For marathons, the recommended pacing profile is even paced in stable environmental conditions, leading to optimal energy consumption, and avoiding premature fatigue before the race finishes. To our knowledge, most of the studies analysing ultramarathon pacing profiles have been done on races consisting of either flat roads, athletic tracks, or trail routes. These events all exceeded 100km or 24hours. There is no consensus as to which pacing profile is the most optimal to improve performance in the ultradistance.

One of the most popular ultramarathon races is the Comrades Marathon, in South Africa, which hosts runners of all levels, from all over the world. Despite this, no study has investigated the pacing strategies used in this race. Determining the optimal distribution of pace can improve the knowledge of runners (recreational and elite) as to how to approach the race and help them to successfully complete the ultramarathon to the best of their ability. This knowledge can benefit coaches in the preparation and execution plan of the Comrades. Future research should also consider including the female runners in the race.

CHAPTER 3: A comparison of the pacing profiles of male runners in the Comrades Marathon "up" run.

3.1 Introduction

The motivation to participate in ultramarathon races varies between runners. However, they all share a common goal, which is to complete the race successfully. Regardless of the personal goal, pacing efficiently during the race is a fundamental component to achieving the desired goal. If the runner selects a pace during the race that is too fast or too variable it could lead to an increase in energy expenditure and peripheral fatigue, and result in the runner underperforming or potentially not finishing the race (48).

In marathon racing, it is suggested that even pacing is the most effective pacing profile, but this cannot be generalised for ultramarathon races, as previously discussed (37). When considering a pacing "strategy" to complete an ultramarathon such as Comrades Marathon, which has an undulating profile, the runner or coach need to consider the runner's strengths and weaknesses regarding the up hills, down hills, and flatter sections. Top runners compete to attempt to win, to get a podium finish, or a "top 10" position and run at a speed that can be tactical and be dictated by the leading pack of runners. This is not necessarily specific to their physiological capacity and could result in them fatiguing prematurely and slowing down in the second half of the race (20). This phenomenon, known as the "herd principle", influences runners' decision making with regards to their pacing "strategy" and often occurs in recreational runners too (20). Most recreational runners strive to complete the race in a certain time or to qualify for a specific time-based medal. Identifying the most optimal pacing profile in an ultramarathon, such as the Comrades Marathon, is yet to be investigated.

The Comrades Marathon "up" run is notorious for its five major hills, known as the "Big 5". In order they are: Cowies Hill at 15km into the race, Fields Hill at 22km, Botha's Hill at 35km, Inchanga at 45km and Polly Shorts at 79km into the race (8). The first half of the race consists of three of the big five hills, making it challenging and crucial to pace effectively to finish the race in the fastest time possible (8). Knowledge of effective pacing in ultramarathons could empower runners and coaches to plan a racing strategy specific to the runners' goals and result in them successfully achieving them.

3.2 Methodology

3.2.1 Study Design

The purpose of this study was to analyse the race results of three years of the Comrades Marathon "up" run, namely 2015, 2017 and 2019, and to determine the pacing profiles of male runners, from the fastest to slowest quartile. This study uses a retrospective study design.

3.2.2 Data Collection

The study made use of publicly accessible data on the Comrades Marathon website (www.comrades.com) (29). These results (2015-2019) were obtained from the Comrades Marathon race director in spreadsheet format. These data included all the split times for each runner, taken at numerous timing check points throughout the race, using electronic timing chips provided by the race's official timing company. This resulted in a sample size of approximately 35 000 runners. The purpose of including three years of data was to prevent the influence of extreme environmental conditions or minor route changes from influencing the outcome of the pacing profiles as well as to increase sample size. Where minor route changes did occur, the terrain remained unchanged, and the major hills were still included in the race route. No adverse weather conditions were reported during the races in the three years.

3.2.3 Data Analysis

To analyse the data, the six timing check points within the race and the finishing time of each runner, were used (Table 3.1). The mean speed ($km \cdot h^{-1}$) for each segment (one check point to the next), and the overall pace was calculated for each runner.

The runners who came in the top 10 of each race were considered "elite" runners and were considered for the second part of the study. Their most recent personal best marathon time was accessed via the ARRS website (http://arrs.august.in/ and http://www.arrs.run), and used to compare the pacing profiles in the comrades marathon against the runners personal best marathon pace. This approximated to a sample size of 30 runners.

Table 3.1: The location of the timing points in the Comrades Marathon race (Durban to Pietermaritzburg)

Timing Check Point	Distance in the race	Percentage of race distance
Pinetown	18.56km	21.3%
Drummond	43.03km	49.6%
Cato Ridge	56.89km	65.5%
Umlaas Road	67.02km	77.2%
Polly Shorts	79.26km	91.3%
Finish Line	86.83km	100%

3.2.3 Participants

3.2.3.1 Inclusion Criteria

Three complete Comrades Marathon "up" run race results were include for analysis. This included 2015, 2017 and 2019. The entire database of each race was used in this study, thus including all male runners who finished the race within the cut-off time of 12 hours. From these results, the top 10 male runners[1] in each race were used to establish the pacing profile of the elite runners, in relation to a recent best marathon pace.

3.2.3.2 Exclusion Criteria

Only three years of data was used because it was only in these years that there were sufficient time points along the route to enable pacing analysis. Runners' results were excluded if split times were missing, or the data was incompletely loaded or if any runners featured in two or more races. If runners featured in two or more races, then only their fastest finishing time was considered for the study. Runners were excluded, in the second section of the study, if their most recent marathon best time was not accessible or if they had not run a marathon within five years of their Comrades Marathon.

[1] The top 10 runners receive gold medals and that is the reason for considering them "elite" and isolating them from the rest of the field.

3.2.3.4 Sampling

The Comrades Marathon Association provided the raw race data from the races in 2015, 2017 and 2019. This resulted in the data of a total of 34 965 male runners (n=13 380 in 2019; n=11 148 in 2017 and n=10 437 in 2015) for analysis.

In the second part of the study, six of the 30 elite runners were excluded from the study, due to the investigators not being successful in retrieving a recent best marathon time.

3.2.4 Analysis of Data

3.2.4.1 Data Preparation

The data was initially combined into a single database using Microsoft Excel spreadsheets. Subsequently, any runners who had raced more than one race were removed and only their fastest time was kept. Runners who had data missing at any check point were then excluded. This resulted in a total of 22 199 runners that were included in the study across the three years of races. The entire database of runners was then arranged in descending order according to finishing times (fastest to slowest) and then divided it into quartiles (Group 1-Group 4). The groups were determined by subtracting the fastest time from the cut off time (12 hours minus 5 hours 31 minutes) and then divided into quartiles (Table 3.2). This provided four groups at 1.67 hours intervals. Group one (the fastest quartile) had the smallest number of runners (n=503) consisting of 2.3% of the field and Group four (the last and slowest group) had the greatest number of runners (n=11 181), consisting of 50,3% of the field. Group two consisted of 3468 runners and group three had 7047 runners. Statistical tests were performed to compare the pacing profiles between the fastest quartile (top 25% of the field), those who finished from 25% to top 50%, from 50% to 75%, and the final quartile from 75% to 100% (i.e. the last 1.67 hours of the race).

The exact location of the six timing check points varied slightly over the three years and thus the percentage of race distance was calculated for each segment. The exact distance and time were used for each year and then subsequently normalised to a single distance divided by the percentage of total race distance to enable ranking from fastest to slowest through the entire database (Table 3.2). Each runner's pace ($km \cdot h^{-1}$) was calculated for the six segments within the race. Table 3.3 illustrates the location of the five major hills within the segments of the race, which provides insight and context to any change in pace.

Table 3.2 The four groups divided according to their finishing time at 1.67-hour intervals.

Group/ quartile	Number of runners	The fastest finishing time in the group (hh:mm:ss)	The slowest finishing time in the group (hh:mm:ss)
Group 1	503	5:31:33	7:11:33
Group 2	3468	7:11:42	8:51:56
Group 3	7047	8:52:00	10:32:08
Group 4	11181	10:32:10	12:00:00

Table 3.3 The race route divided into six segments according to the timing check points.

	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Segment location	Start to Pinetown	Pinetown to Drummond	Drummond to Cato Ridge	Cato Ridge to Umlaas Road	Umlaas Road to Polly Shorts	Polly Shorts to Finish line
Segment length (km)	18.56	24.49	13.84	10.13	12.24	7.57km
Major Hills	Cowies Hill	Fields Hill and Botha's Hill	Inchanga		Polly Shorts	
Route description (8, 55)	Predominantly up hill, Cowies Hill ascent and decent into Pinetown	Long uphill from Fields hill to Botha's Hill, with various gradients of up hills for 15km. First 2km of Fields Hill is steep and the last 2.7km of Botha's Hill is also steep. Descent from the top of Bothas' Hill into Drummond	3.5km – 4km steep climb up Inchanga and decent into Cato Ridge.	The route profile tends downwards from Cato Ridge with gentle climbs ±100m in length to Umlaas River	Route tends downwards from Umlaas until steep short (1.7km) climb of Polly Shorts	Downhill from Polly Shorts until a short climb at 6km from the finish.

3.2.4.1 Statistical Analysis

Appropriate statistical procedures, details of which follow (below), were performed to determine any significant differences in the data. Means and standard error (SE) were calculated, and line plots generated to visualize the average running pace per segment (split) and group. These figures show the characteristics of the dataset and patterns in the running pace of the groups.

RStudio was used for data analysis and the glmmTMB package used to perform a Gaussian Generalised Linear Mixed-effects model (GLMM), to assess if there was a statistically significant difference ($P < 0.05$) in pacing profiles between the four groups (quartiles) that were assigned (56). Running time was recorded by the race timing company at each of the six timing segments for each runner. A subject-specific random effect was incorporated into the model to account for within-subject correlation resulting from repeated measures (57).

Once a statistically significant difference was identified, a post-hoc comparison using the Tukey method was conducted to identify specific mean values that exhibited significant differences among the groups. The Tukey method was chosen because it is widely recognized for its ability to control for multiple comparisons when comparing means, thereby ensuring reliability and robustness of the findings.

The second part of this study compares the pacing profiles of the elite (top 10) male runners in each race, relative to their recent marathon personal best times. The mean running pace of each runner, across each of the six segments, was normalised to their mean marathon pace. The pace was described as a percentage of their marathon pace and was graphically illustrated for each runner, for each year in separate graphs. Due to the limited sample size, a Cohen's d (1988) test was used to describe the effect size when comparing the pace of first half of the race to the second half of the race for the elite runners.

3.2.5 Ethical and Regulatory Compliance

The study was conducted in accordance with South African Good Clinical Practice (GCP). Prior to data collection, approval was obtained from the University of Cape Town's Health Sciences Human Research Ethics Committee (HREC REF 287/2022, Appendix II). The study adhered to the principles of the Declaration of Helsinki (World Health Association, 2017). This study also adhered to the Protection of Personal Information (POPI) Act, No 4 of 2013, which promotes the protection of personal information by public and private bodies.

3.2.5.1 Confidentiality

The data used in this study (race results), extends over three years and has been publicly available ever since the races took place (www.comrades.com). However, considering that the data obtained from the race results contains personal information such as names, surnames and running club names, the data was stored in a password protected file. For the most part of the study, the runners' names and surnames are of no relevance and each runner included in the study was therefore allocated a number. It was only necessary to have the names and surnames to identify runners who featured in more than one event, to remove the duplicates and to identify their fastest finishing times. It was also necessary to identify the first 10 runners of each year, by name and surnames, to source their personal best marathon time from an additional database. Once obtained, names were removed from the data. The data will be retained for five years, after which it will be deleted. The participants data and individual names will remain anonymous in any publication.

3.2.5.3 Conflicts of Interest

There are no conflicts of interest by the researchers.

3.3 Results

3.3.1 Participants

The race results revealed that a total of 34 965 male runners participated in the Comrades Marathon" up" run in 2015, 2017 and 2019. Runners who participated in more than one race were classified as "duplicates" and for statistical reasons, only their fastest time was included for analysis. This resulted in 10 280 duplicates being excluded. Additionally, 2486 runners were excluded for having data missing at one or more timing check point. This left a total of 22 199 male race results for analysis.

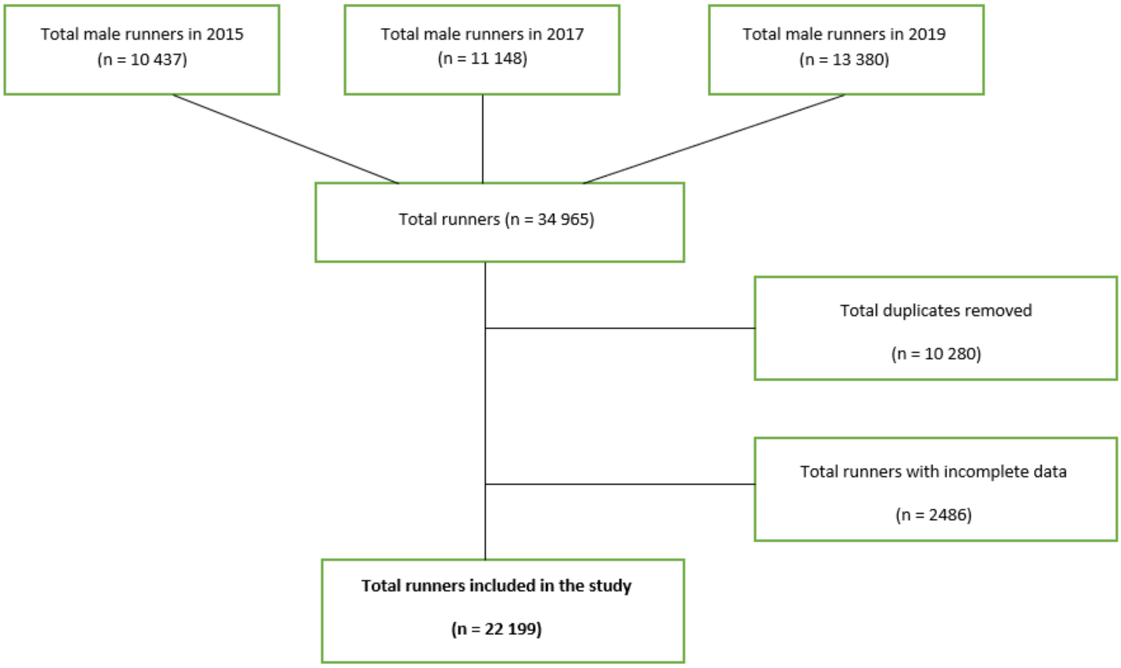

Figure 3.1: Summary of the study sample for the first section of the study

The second part of the study only considered the elite runners (top 10 runners of each race) and compared their pacing in the race to their most recent best marathon time. Only 23 runners were included due to a recent marathon time for six of the runners not being located from any race results database.

3.3.2 Analysis of Running Speed

Segments one and two were in the first half of the race and segment four to six were in the second half (Table 3.3). The distance of each segment varied. Segment one was 18.56km, segment two (the longest) was 24.49km, segment three was 13.84km, segment four was 10.13km, segment five was 12.24km and segment six (the shortest) was 7.57km long.

Figure 3.2 shows the change in pace across the six segments for the four groups. The mean and Standard Error (SE) of the overall race speed and running speed between each segment were calculated for each group (Table 3.4). Table 3.4 shows a pairwise comparison of mean pace between each group at each segment in the race. The SE and upper and lower Confidence Level's (CL) were also identified. As would be expected due to the way in which the groups were derived, there was a significant difference in mean pace between the four groups (P<0.01). All four groups paced similarly, reducing their pace in the middle of the race, and speeding up again in the final segment (Figure 3.2).

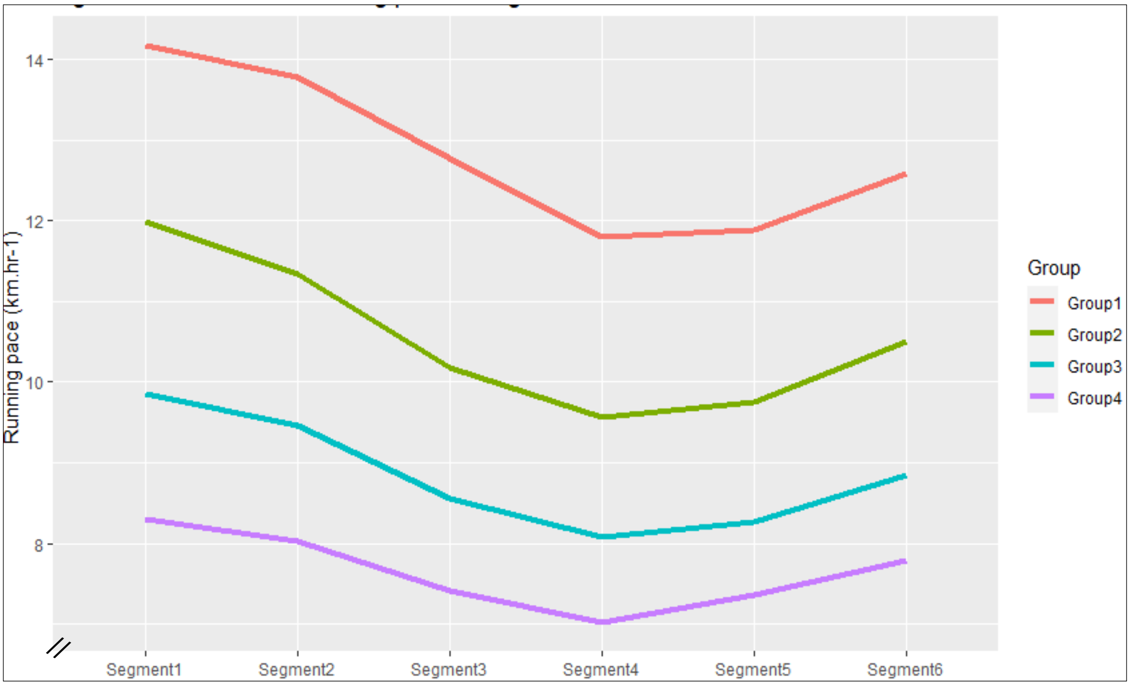

Figure 3.3: The distribution of running speed of the four groups of male runners, throughout the Comrades Marathon

Table 3.4 Pairwise comparison of mean pace between groups at each segment in the race

	Group	Mean $(km \cdot h^{-1})$	Standard Error of mean speed	Lower Confidence level $(km \cdot h^{-1})$	Upper Confidence level $(km \cdot h^{-1})$
Segment 1 (25% into the race)					
	Group 1	14.17	0.033679	14.10	14.24
	Group 2	11.98	0.012820	11.95	12.01
	Group 3	9.86	0.008998	9.84	9.88
	Group 4	8.30	0.007143	8.27	8.31
Segment 2 (49% into the race)					
	Group 1	13.78	0.033679	13.71	13.84
	Group 2	11.34	0.012820	11.32	11.37
	Group 3	9.46	0.008998	9.44	9.47
	Group 4	8.02	0.007143	8.01	8.04
Segment 3 (65.6% into the race)					
	Group 1	12.78	0.033679	12.71	12.84
	Group 2	10.17	0.012820	10.15	10.20
	Group 3	8.55	0.008998	8.53	8.57
	Group 4	7.42	0.007143	7.40	7.43
Segment 4 (78.2% into the race)					
	Group 1	11.80	0.033679	11.74	11.87
	Group 2	9.57	0.012820	9.54	9.59
	Group 3	8.08	0.008998	8.06	8.09
	Group 4	7.02	0.007143	7.01	7.03
Segment 5 (91.3% into the race)					
	Group 1	11.88	0.033679	11.82	11.95
	Group 2	9.75	0.012820	9.72	9.77
	Group 3	8.27	0.008998	8.25	8.28

	Group	Mean (km·h^{-1})	Standard Error of mean speed	Lower Confidence level (km·h^{-1})	Upper Confidence level (km·h^{-1})
	Group 4	7.36	0.007143	7.35	7.38
Segment 6 (at the finish)					
	Group 1	12.59	0.033679	12.52	12.66
	Group 2	10.50	0.012820	10.47	10.52
	Group 3	8.85	0.008998	8.83	8.87
	Group 4	7.78	0.007143	7.77	7.79

3.3.3 Pacing Relative to the Mean Pace of the Race.

To determine if there was a significant difference in pacing between the four groups, the data was normalised by assigning the mean race pace of each runner to 100%, and then calculating race speed at the six segments as a percentage of this (Table 3.5). A pairwise comparison of the means at each segment was then performed to identify any significant difference in pace between the groups (Table 3.6). All the groups started the race (segment one) faster than their mean race pace, with group two starting the fastest, averaging 112% of their mean race pace at segment one. Group four started the most conservatively at 108% of their mean race pace. Group one and three also paced more conservatively than group two, averaging 109% and 110%, respectively, of their mean race speed at segment one and slowing down to 106% at segment two. All four groups ran faster than their mean race pace in the first two segments of the race (Table 3.5 and Figure 3.3).

All groups slow down between segment two until segment four, where all groups increase their pace towards the end of the race. Group one averaged 98.6% of their mean race pace at segment three and 91.1% at segment four. Group two averaged 95.7% and 90.2%, respectfully. Group three averaged 96.2% of their mean race pace at segment three and 90.8% at segment four and group four averaged 96.8% and 91.89%, respectfully. At segment five and six, Group one increased their pace and averaged 91.74% and 97.33% of their mean race pace. Group two averaged 91.75% at segment five and increased to 98.8% of their mean race pace at segment 6. Group three averaged 93.0% at segment five and increased their pace to 99.6% of their mean race pace in the final segment. Group four showed the greatest increase in pace in the last two segments, compared to the other three groups, and average 96.1% at segment five and paced at 101,6% relative to their mean race pace in segment six.

In a pairwise comparison, the p-value was set at <0.05 for a significant difference. Groups two and four ($p<0.001$), and groups three and four ($p<0.001$) paced significantly differently across all six segments (Table 3.6). This is illustrated in Figure 3.3, which shows the distribution of running pace across all the segments of the race, relative to mean race pace. There was a significant difference in pacing between all four groups at segment one, segment three, and the final segment of the race ($p <0.05$) (Figure 3.4). There was no significant difference found in the pacing between group one and the other three groups at segment four. At segment two, there was a significant difference between group four and the other three groups but no significant difference between groups one and two ($p= 0.799$) and groups two and three (P0.0359) or groups one and three ($p=0.993$).

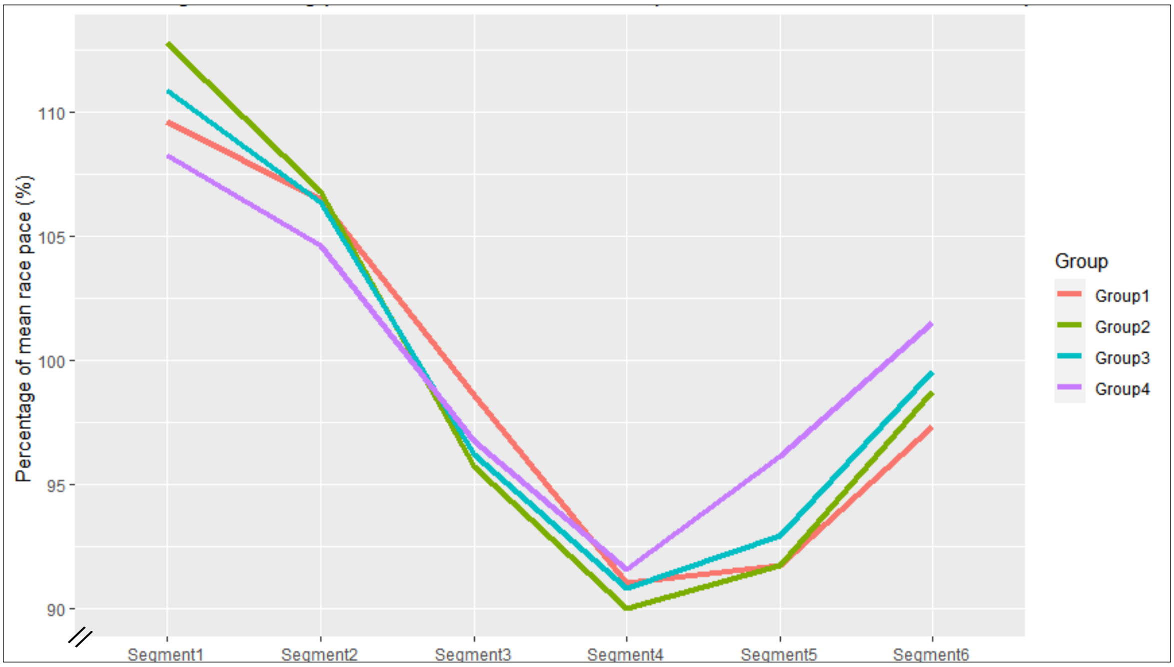

Figure 3.3 Pairwise comparison of the groups' running pace at each segment relative to their mean race pace.

Table 3.5 Pairwise comparison of means of each group (normalised to mean race speed and expressed as a percentage) at each segment in the race.

	Group	*Mean	SE	Lower CL (%)	Upper CL (%)
Segment 1					
	Group 1	109.6	0.31671	109.0	110.2
	Group 2	112.8	0.12062	112.5	113.0
	Group 3	110.9	0.08461	110.7	111.1
	Group 4	108.3	0.06717	108.1	108.4
Segment 2					
	Group 1	106.5	0.31671	105.8	107.1
	Group 2	106.8	0.12062	106.5	107.0
	Group 3	106.4	0.08461	106.2	106.5
	Group 4	104.6	0.06717	104.5	104.8
Segment 3					
	Group 1	98.6	0.31671	98.0	99.2
	Group 2	95.7	0.12062	95.5	96.0
	Group 3	96.2	0.08461	96.0	96.4
	Group 4	96.8	0.06717	96.6	96.9
Segment 4					
	Group 1	91.1	0.31671	90.5	91.7
	Group 2	90.0	0.12062	89.8	90.3
	Group 3	90.8	0.08461	90.7	91.0
	Group 4	91.9	0.06717	91.5	96.9
Segment 5					
	Group 1	91.7	0.31671	91.1	92.3
	Group 2	91.8	0.12062	91.5	92.0
	Group 3	93.0	0.08461	92.8	93.1
	Group 4	96.1	0.06717	96.0	96.3

	Group	*Mean	SE	Lower CL (%)	Upper CL (%)
Segment 6					
	Group 1	97.3	0.31671	96.7	98.0
	Group 2	98.8	0.12062	98.5	99.0
	Group 3	99.6	0.08461	99.4	99.7
	Group 4	101.5	0.06717	101.4	101.7

*Mean expressed as a % of mean race speed

df = 133168

Table 3.6. P-Values of pairwise comparison between groups at each segment, relative to mean race pace.

Group	SE	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Group 1 - Group 2	0.339	<0.0001	0.7990*	<0.0001	0.0104*	1.0000*	0.0001
Group 1 - Group 3	0.328	0.0006	0.9933*	<0.0001	0.8854*	0.001	<0.0001
Group 1 - Group 4	0.324	0.0002	<0.0001	<0.0001	0.3854*	<0.0001	<0.0001
Group 2 - Group 3	0.174	<0.0001	0.0359*	0.0090	<0.0001	<0.0001	<0.0001
Group 2 - Group 4	0.138	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Group 3 - Group 4	0.108	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

*No significant difference identified

3.3.3 Pacing Relative to the First Segment of the Race.

A similar pairwise comparison was performed to determine how the groups paced relative to the speed at which they started the race (segment 1). The race pace at each segment was normalised to the pace of segment one, with segment one equal to 100% (Table 3.7). Figure 3.4 illustrates a parabola shaped pacing profile for all the groups. All groups reduced their pace until segment four, after which they all increased the pace in the last two segments, segments five and six.

The pace slowed down the most for group two (80.6% of starting pace), compared to the other groups, until segment four. All four groups ran the first segment faster than their last segment, with group four showing the greatest increase in pace in segments five (89.6%) and six (94.7%) relative to the first segment. In contrast, group four showed the smallest difference in pace between segments two and six (5%). Groups three and four showed a greater increase in pace in the last segment (90.9% and 94.7%, respectively), compared to groups one (89.2%) and two (88%), when pace was normalised to segment one.

Table 3.8 highlights where the significant differences in pacing lie between the groups. The p-values at each segment show that groups one and two ($p = 0.03$), two and three ($p < 0.0001$), groups two and four ($p < 0.0001$), and groups three and four ($p < 0.0001$) paced significantly differently across all six segments of the race, when pace was normalised to the first segment. There was no significant difference in pace between groups one and three at segment two, segment four and segment five and groups one and four had no significant difference in pace at segment two and three, when pace was normalised to segment one.

Table 3.7: Pairwise comparison of mean pace, normalised to the pace at segment one for each group

	Group	*Mean	SE	*Lower CL (%)	*Upper CL (%)
Segment 2					
	Group 1	97.3	0.43242	96.5	98.2
	Group 2	95.2	0.16468	94.8	95.5
	Group 3	96.6	0.11553	96.4	96.8
	Group 4	97.1	0.09172	97.0	97.3
Segment 3					
	Group 1	90.4	0.43242	89.6	91.3
	Group 2	85.7	0.16468	85.4	86.0
	Group 3	87.7	0.11553	87.5	87.9
	Group 4	90.1	0.09172	89.9	90.3
Segment 4					
	Group 1	83.6	0.43242	82.8	84.5
	Group 2	80.6	0.16468	80.3	80.9
	Group 3	82.9	0.11553	82.7	83.1
	Group 4	85.3	0.09172	85.2	85.5
Segment 5					
	Group 1	84.2	0.43242	83.3	85.0
	Group 2	82.1	0.16468	81.8	82.4
	Group 3	84.8	0.11553	84.6	85.1
	Group 4	89.6	0.09172	89.4	89.8
Segment 6					
	Group 1	89.2	0.43242	88.4	90.1
	Group 2	88.4	0.16468	88.1	88.7
	Group 3	90.9	0.11553	90.7	91.2
	Group 4	94.7	0.09172	94.5	94.9

Group	*Mean	SE	*Lower CL (%)	*Upper CL (%)

Segment 1 Mean for all groups = 100%

df = 133168

*Mean and **CL measured in % of segment one

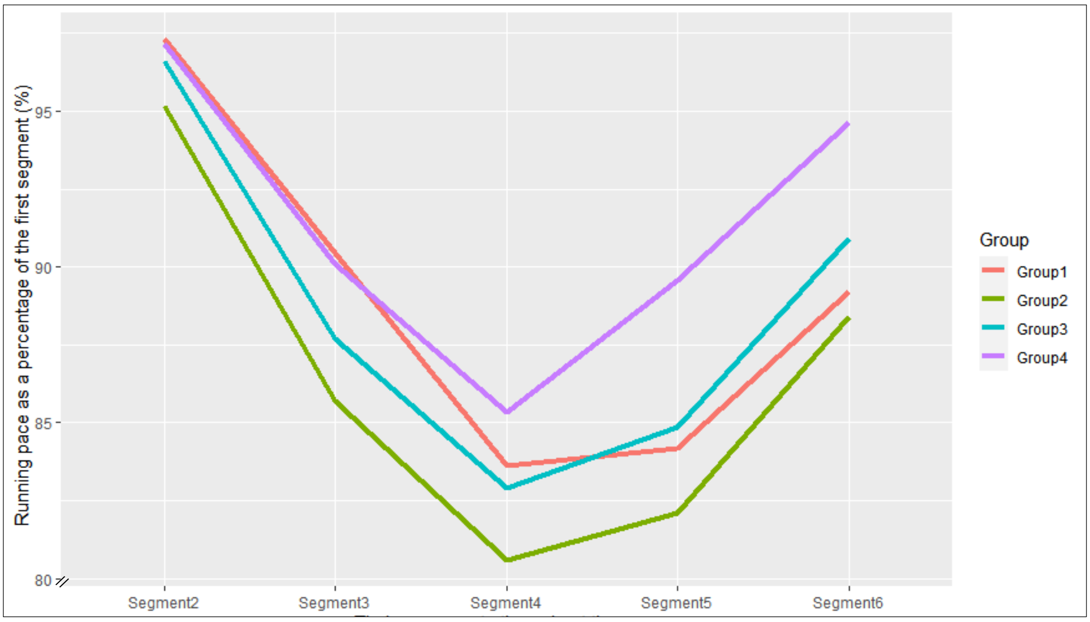

Figure 3.4: The pairwise comparison of running pace, normalised to segment one, between the groups at each segment of the race.

Table 3.8: P-Values of pairwise difference between groups, at each segment, relative to segment one.

Group	SE	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Group 1 – Group 2	0.463	<0.0001	<0.0001	<0.0001	<0.0001	0.0301
Group 1 - Group 3	0.448	0.3621*	<0.0001	0.375*	0.4257*	0.0006
Group 1 - Group 4	0.442	0.9795*	0.8733*	0.0005	<0.0001	<0.0001
Group 2 – Group 3	0.201	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Group 2 – Group 4	0.188	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Group 3 – Group 4	0.148	0.0009	<0.0001	<0.0001	<0.0001	<0.0001

*No significant difference

3.3.4 Comparing the Elite Male Runners' Comrades Marathon Pace to their Most Recent Best Marathon Pace.

The top 10 runners were identified in each race, and their most recent marathon times were sourced. Due to the small number of runners (n = 23) in the elite group, a statistical analysis could not be performed to determine if there is a statistically significant difference in running pace between the winners and the runners who came tenth.

To determine how the elite runners' pace in the Comrades Marathon in comparison to a standard marathon, a comparison was made between their Comrades Marathon pace and their pace in a recent best marathon (within five years of their Comrades Marathon pace being analysed). Their marathon pace was assigned a value of 100% and the pace at each segment of the Comrades Marathon was expressed relative to this pace (Table 3.9). Secondly, the runners' average pace in the Comrades Marathon was expressed relative to their marathon pace (Table 3.10). The elite runners started the race at an average of 87.8% of marathon pace and averaged the same pace for the rest of the race. The winner in 2015 started the race at 95% of his marathon pace and ran an average pace of 97% for the race (Table 3.9). However, the marathon time identified for this runner was much slower than the rest of the elite runners, which could indicate that his marathon time used in this analysis was not a recent "best" time.

In addition, a Cohen's d (1988) was performed to determine the effect size of the difference in pace between the first half of the race and the second half of the race, in the elite runners, relative to their marathon pace (58). On average, these runners ran the first half of the race faster than the second half of the race, with a moderate effect size (ES = 0.65).

Table 3.9 The elite runners of 2015, 2017 and 2019 Comrades Marathon pace at each segment relative to their recent best marathon pace.

Year	Position in race	Segment 1 (%)	Segment 2 (%)	Segment 3 (%)	Segment 4 (%)	Segment 5 (%)	Segment 6 (%)
2015	1	95.35	97.27	100.22	95.64	102.50	93.85
	2	88.87	90.56	95.70	82.01	87.54	83.51
	3	87.70	89.94	93.14	85.67	83.44	78.05
	5	88.24	91.12	87.48	80.39	85.95	81.12
	6	83.72	85.28	87.88	74.47	75.89	74.88
	7	90.07	91.51	93.27	81.10	83.88	76.80
	8	89.77	91.41	94.18	79.46	83.10	74.21
	9	90.29	90.61	85.13	79.25	88.03	82.60
2017	1	88.37	90.85	91.92	93.28	96.84	95.58
	2	86.26	88.70	89.71	91.06	92.16	87.00
	4	87.39	89.75	90.85	90.93	87.91	86.84
	5	86.39	88.59	90.27	80.95	80.64	89.62
	6	86.63	89.03	89.72	83.16	84.51	91.23
	7	83.11	86.15	86.93	86.20	79.70	79.64
	8	86.06	88.19	88.08	84.19	85.78	87.81
	9	85.89	87.18	87.40	84.02	86.55	86.07
	10	86.68	87.51	87.76	83.72	88.39	89.11
2019	1	88.48	89.45	91.21	91.56	89.16	86.66
	3	84.05	84.98	86.66	84.12	76.08	79.43
	4	90.78	91.82	91.94	84.27	82.01	84.53
	5	88.22	89.24	90.98	88.77	76.80	75.05

6	86.47	87.49	89.31	88.43	75.55	70.50
7	89.40	87.33	88.44	87.91	87.67	87.98
9	104.05	105.24	105.17	97.97	88.68	80.98

Table 3.10: A comparison of the elite runners' Comrades Marathon pace in the first segment of the race and average race pace compared to their recent best marathon pace.

Year	Position in the race	Segment one relative to marathon pace (%)	Mean race pace relative to marathon pace (%)	Marathon pace (km·h^{-1})
2015	1	95.4	97.5	16.0*
	2	88.9	88.0	17.1
	3	87.7	86.3	17.3
	5	88.2	85.7	17.1
	6	83.7	80.4	18.2
	7	90.1	86.1	16.9
	8	89.8	85.4	17.0
	9	90.3	86.0	16.9
2017	1	88.4	92.8	16.9
	2	86.3	89.2	17.3
	4	87.4	89.0	17.1
	5	86.9	86.1	17.5
	6	86.6	87.4	17.0
	7	83.1	83.6	17.8
	8	86.1	86.7	17.3
	9	85.9	86.2	17.2
	10	86.7	87.0	17.1
2019	1	88.5	89.5	17.6
	3	84.1	82.6	18.5
	4	90.8	87.6	17.1
	5	88.2	84.0	17.6
	6	86.5	83.0	18.0

7	89.4	88.1	17.1

*It is assumed that this runner did not “race” his marathon due to his marathon pace being slower than the rest of the elite runners and his Comrades Marathon pace being faster than 95% of this marathon pace.

3.5 Discussion

The main finding of the study is that all the groups demonstrated a reverse "J"-shaped pacing profile in the Comrades Marathon "up" run (Figure 3.2). This was regardless of whether speed was expressed normalised to mean race pace (Figure 3.3) or when speed was normalised to the first segment (Figure 3.4). This finding corresponds to the findings of Tan et al. (21) Chatzakis et al. (25), Knechtle et al. (22) and Bossi et al. (18). However, it challenges the findings of Suter (17), a study performed on the hilly Ultra-Trail du Mont Blanc (UTMB), which had over 10,000m of elevation gain over 171km, which showed that less variation in pace was more efficient. This could be due to the limited number of participants in the UTMB due to the elite standard of runners and the challenging qualifying times to participate in this race.

Not surprisingly, the mean pace at which each of the groups completed the race were significantly different, since for the purpose of the research study, the entire race cohort was divided into time-based groups i.e. quartiles (see Methods) (Figure 3.2). When speed at each segment was normalised to mean race pace (Figure 3.3), each group started off much faster than their mean race speed despite the first half containing three of the five major hills in the race (8). The runners in each group subsequently slowed down towards the middle of the race, and then increased their pace in the final segment, resulting in an "end spurt". Similarly, when pace was normalised to the first segment, all four groups ran the first segment faster than their last segment, with group four showing the greatest increase in pace in segments five and six (Figure 3.4). All the groups showed a reduction in pace after segment two (halfway) despite the second half of the race being predominantly downhill with rolling hills (55), described as "flatter and easier" (8). In addition, group one and two show the biggest variation in pace between segment one and six (Table 3.7), whereas the slower runners, in group four, show the smallest variation in pace between segments one and six. Similarly, the elite runners displayed a positive pacing profile, when comparing their average pace in the first and second half of the race. This contradicts the general consensus that faster runners display less variation in running pace over ultramarathon distances (10, 21). The data demonstrates that group one and two consists of the smaller number of runners (n=503 and n=3468 respectfully), which could influence the results due to the vast range of abilities within each group, compared to group four, which consisted of 11181 runners. The undulating profile of the race would also have contributed to the variation in pace throughout the race. The faster runners aim to achieve a specific medal (Gold and Silver) and may be ambitious with their pacing to try and maintain the pace set by the leading runners, whereas the slower runners (Group four) adopt a more conservative approach relative to their own ability, with the aim to finish the race before the cut off. However, important for the discussion of pacing in this study, all runners in all the groups were exposed to the same variation in elevation, and altitude gains and losses.

In this study, group one cannot be classified as being only the elite runners, because this group contained the race winners and top 10 finishers (elite runners), as well as those who finished 1-hour 30 minutes after the winner. Thus, there is quite a large spread of ability within the group. It is assumed that the majority of the elite runners who start the race as potential top 10 finishers, run as a pack and attempt to maintain the pace set by the main contenders, a phenomenon known as "herd mentality" (12, 21). This could lead to some runners running faster than what they physiologically should be, and not being able to maintain the pace of the group and consequently running significantly slower towards the end of the race.

In 2017, elite runners started to run in shoes with advanced foot technology (AFT) in attempts to break the marathon world record. Since then, it has gained popularity amongst elite and recreational runners striving to improve their personal best times. The introduction of running shoes with a curved carbon plate in the midsole of the shoe, has shown to significantly improve marathon running pace in elite runners (59). The new AFT is said to improve running economy by 2-6% and the effects in marathon running have been compared to erythropoietin doping (59). However, the effect of wearing carbon plated shoes on pacing during the Comrades Marathon, or in other ultramarathon distance races, and in recreational runners is not known. There is a wide individual variability in response to the shoes. Only 75% of marathon runners improved their pace when using carbon shoes (59). It is also unknown whether the placebo effect of wearing shoes with AFT contributes to the improved performance in recreational runners.

The runners who won the Comrades Marathon in 2017 and 2019 ran the first segment of the race at 88% of their standard marathon pace and the winner in 2015 ran the first segment of the race at a pace of 95% of his marathon pace and continued to maintain the pace over the duration of the race (Table 3.9 and 3.10). This seems unrealistically high; it is possible that his marathon time used in this analysis was not a true reflection of the speed he was capable of in a standard marathon race at the time. This runner aside, the majority of the top 10 runners in each year averaged between 80 and 90% of their marathon pace in the Comrades Marathon (Table 3.10).

The rest of group one may pace differently to obtain a silver medal. These runners might form small packs with other runners of a similar pace, aiming to maintain the intensity for as long as possible (21). However, if the runners' goals for the race are unrealistically fast, coupled with their excitement at the start and lack of fatigue at the beginning of the race, they may start too fast relative to their physiological ability, resulting in a subsequent greater than expected slowing later in the race. This has been seen as inefficient pacing in the ultramarathon distance (25).

Segment one is located between the start of the race in Durban to Pinetown, which consisted of 18.56km of undulating terrain and reaches a maximum elevation of 400m (29), which is followed by segment two, which includes a 5km steep climb followed by 5km of modest climbing; the route is then undulating terrain for the next 15km to the halfway point at Drummond. The overall elevation gains between segment one and two is 750m and thus it is expected that pace between these segments may be slow. The slower runners (group four) may pace faster than expected at this point (Drummond) to meet the "cut off" time and not being allowed to finish, after which they reduce their pace to recover, or the reduction in pace could be due to the accumulation of the fatigue that has built up from the hilly, first half of the race. This is suggested by the reduction in pace when speed in the second and third segment is compared to the first segment, in all four groups (Figure 3.3 and 3.4). Figure 3.3 illustrates the rapid reduction in pace for group two and three between segments two and three, compared to group one and group four. However, each group paced significantly differently in segment three ($P<0.001$), relative to their mean race pace. The reduction in pace could reflect the unrealistic goals set by inexperienced runners, whereas the faster runners chase the leading pack of runners. The slower runners (Group four), run in packs with the pace dictated to by the numerous pace setters within the group. This could have contributed to why they show less in variation in pace from segment one to six, compared to the faster runners. In addition, the large number of runners in group four could also result in runners "bunching" within the race, consequently slowing down the pace at which they are running.

The nature of the route profile between Drummond to Cato ridge (third segment) and Cato Ridge to Umlaas Road (fourth segment), is undulating with a gradual increase in overall elevation to Umlaas Road (the highest point in the race at 810m). The data of this study demonstrates that all the groups pace the slowest at segment four (78% of the race distance) before gradually increasing the pace again at segment five and six (Figure 3.3 and 3.4). The steep climb up to Umlaas Road at 77% of the race distance, is located between segment three and four and this could contribute to all the groups slowing down at this segment. Presumably, the faster runners compensate for the loss in time during segment four, by running the segments before and after faster. Group two and three continued to follow a similar pacing profile (Figure 3.3) throughout the race, despite pacing significantly differently between segment four, five and six (Table 3.6), relative to mean race speed. It may be that these runners aimed to finish the race within a specific time, to receive a particular medal. The faster runners in group two aim to achieve a silver medal, whereas the slower runners in this group, and the faster runners in group three, aim for the Bill Rowen Medal (finish under 9 hours). As the runners descend from Umlaas Road towards the end of the race, the terrain continues to follow an undulating profile but with a bias to downhill for the last 20km to the finish which would assist in maintaining a faster pace.

Regardless of performance, the four groups increased their pace in the final segment of the race, pacing significantly different ($P<0.005$) (Table 3.6 and 3.8), despite having to climb the infamous “Polly Shorts” (Figure 3.3 and 3.4). Polly Shorts is described as a short and steep hill, but due to its location in the race, it has a reputation for being one of the toughest climbs (91% of race distance) (8). Group four showed the greatest increase in pace over the final two segments, when pace was normalised to the first segments (89.2% and 94.7%, respectfully) and when pace was normalised to mean race pace (101.5%). This is in accordance with previous work that has identified an “end spurt” phenomenon as runners approach the finish line (18, 21, 41). The motivation of reaching the final segment, together with the downhill nature of the course towards the finish, allows top runners to make up some time without the concern of fatigue and slower runners resist walking in the last 8km to make various cut off times. It is widely known that the slowest-runners (group four) spend a substantial part of the second half of the race walking or alternating between walking and running (29, 38). It is likely that these runners ran more than they walked in the final segment, to ensure they finished under 11 hours (Bronze Medal) or finished the race within the cut off time (12hrs). This would explain the increase in speed in the final segment for these runners (Figure 3.3).

It is suggested that endurance runners who are not striving to win the race or race for prize money, should adopt a conservative and realistic pace in the initial stages of the race and should stay within a pack of runners (13). As previously mentioned, the Comrades Marathon has 15 experienced pace setters or “bus drivers”[2] as they are better known as, ranging from under nine hours to the cut off (60), who run at a specific pace to complete the race in a specific goal time. This obviously influences the pacing of the runners who choose to run in these packs, which in some respects is related to the “herd mentality” previously discussed. There are often two or three pacesetters with the same predicted times, starting at various points of the starting batches. Most of these pacesetters would be located within study groups three and four and could influence the pacing profiles used by runners in these groups. There are only four pacesetters, two at under nine hours and two at nine hours 30 minutes, that are likely to be in group two, also influencing the runners who would like to achieve a specific medal (60). The benefit of running with a pace setter is the continuous encouragement and motivation that

[2] Bus driver or also known as a pacesetter is an identified experienced runner that is responsible to set the pace to achieve a specific goal.

they and the pack of runners expel, which positively influences the runners mood and consequently, their pacing profile (60).

3.5.1 Strengths and Limitations of this Study and Suggestions for Future Studies.

To our knowledge this is the first study investigating the pacing profiles of Comrades Marathon runners. However, this is not the first study to be performed on the ultramarathon race distance, that considers the event over consecutive years, to mitigate external factors such as wind, heat and humidity, which could have influenced the runners' pacing patterns on race day (17, 18, 21, 25). Two studies have been performed on flat routes (21, 25), and one study has been performed on the hilly Ultra Trail Mont Blanc (17). Thus, it is important to note that our findings cannot be generalised for other ultramarathon road races due to the difference in course profile, nor can it be generalised for the Comrades Marathon "down" run.

In this study the database was divided into four groups, based on time to complete the race, which could have "diluted" the performance of the elite runners, in group one. The elite runners in this group could show a different pacing profile versus the rest of the group. Secondly, only the data of the male runners were analysed in this study. It is quite possible that female runners' pace differently and the findings reported here should not be extrapolated to female runners in the Comrades. Indeed, it would be interesting to examine the pacing profile of male and female runners who perform similarly. Previous studies have identified that male and female runners paced differently, and thus male and female runners could demonstrate different pacing profiles in the Comrades Marathon. A similar study should be performed on women and a comparison made between male and female pacing profiles.

This study did not consider training histories or ultramarathon experience that could influence performance on race day (37). Additionally, factors such as age, nutrition, hydration or pretraining physiological and psychological status, were also not considered (30, 61). Older ultramarathon runners might have more experience in pacing themselves if they have completed multiple ultramarathon distances, whereas younger runners may run faster than older runners and may be naive to the difficulty of the ultramarathon distance (22, 30). It has been shown in (standard) marathoners that older female and faster runners were better pacers than younger male and slower runners (22), somewhat mirroring the findings from the 100km Lauf Biel race, in which the best pacers were runners aged 40-44, whereas the younger runners (18-24 years) paced the worst (22). It is recommended that future studies on the performance of male runners, consider the runners' age to compare the pacing strategies of the various age categories in the male field and then compare it to how female runners of the same age categories pace in the same race.

The six segments within the race were not equally distributed throughout the race due to the specific location of the timing check points. This could skew the data when interpreting the pacing profile, as the first half of the race consists of two segments and the second half of the race consists of four segments.

When identifying the elite runners most recent standard marathon times, this comparison became difficult since it was found that some runners had not run a marathon in the year of the Comrades Marathon and some had not attempted a fast standard marathon any time close to the Comrades Marathon (within a year), with their closest fastest marathon race in some cases being four or five years prior to the Comrades race, but nevertheless was the only marathon time available. This could have influenced the comparison of pacing relative to their marathon recent best time, as some of these runners could perhaps have run much faster closer to the year of the Comrades Marathon, or in other cases, their standard marathon pace might have become slower. It is also unknown whether the marathon time used was at personal best effort for these runners. Future studies could compare the pace of the runners' personal best or a fastest marathon, run within a year of completing the Comrades Marathon, to identify a more accurate analyses of pace relative to their marathon times.

Despite these limitations, this study provides a starting point for coaches and runners (of all levels) to plan the training leading up to the event and the pacing strategy on race day.

CHAPTER 4: Conclusion

This study is one of four studies that consider ultramarathon pacing profiles over consecutive years. However, it is the first study performed on a road race with an undulating route profile, with a total elevation gain of ±1000m, for three consecutive years. The results of this study showed that there is no significant difference between the pacing profiles of the faster through to the slowest male runners in the Comrades Marathon "up" run, with all the runners adopting a reverse "J"-shaped pacing profile when their pace was compared to both their mean race pace as well as to the pace in the first segment (split) of the race. This finding is similar to previous studies (18, 21, 22, 25) that found that the most efficient pacing profile in recreational ultramarathon and marathon runners is a parabolic shaped profile, particularly reverse "J"-shaped.

All four running groups followed the same profile of reducing their speed to below their average race pace after reaching halfway in the race, and then increasing their speed in the final segment again (end spurt). However, it must be kept in mind that the race profile changes over the race distance, and thus slowing or speeding up is at least partially influenced by the course profile of the segment being analysed. Nevertheless, all the runners in the race are equally affected in this way. The slowest group of runners increased their speed the most in the final segment, with the assumption that they would reduce the amount of walking in the final few kilometres of the race.

When comparing the elite runners' Comrades Marathon pace relative to their recent best marathon pace, the elite runners start the race at an average of 88% of their marathon pace and maintain an average pace of 80-90% of their standard marathon pace, throughout the race. This study provides a starting point for runners and coaches to plan the training leading up to the race and the pacing strategy for race day.

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APPENDICES

Appendix 1: Letter to Comrades Marathon race director

Division of Physiological Sciences
Department of Human Biology
Faculty of Health Sciences
University of Cape Town
Private Bag X3
Observatory 7935
South Africa
Phone: +27 (0) 21 650 4578
E-mail: Andrew.bosch@uct.ac.za

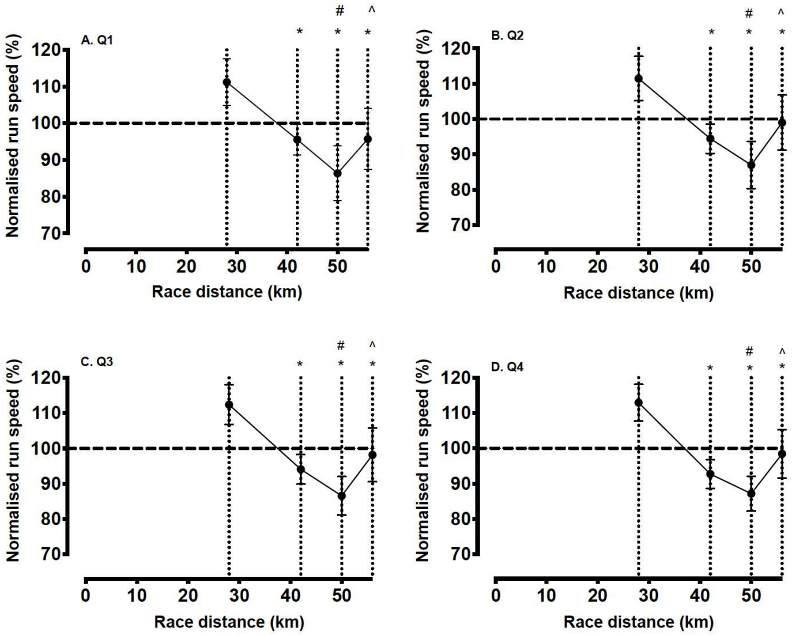
15 September 2022

Dear Comrades Marathon Race Director

I am a Masters student in the division of Physiotherapy at the University of Cape Town, and I am conducting a study to compare the pacing profiles of the elite versus non-elite male runners in the Comrades Marathon "up" run. This study forms part of my MSc Exercise and Sport Physiotherapy programme and has received ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (see attached). The study is being supervised by Professor Andrew Bosch, of the Division of Physiological Sciences, previously known as UCT "Sports Science". While my study will analyse the data of the male runners in the last 10 "up" races, Professor Bosch has other students who will be analysing the race times of the female runners in the "up" race, as well as students who will do the same for the male and female "down" race results.

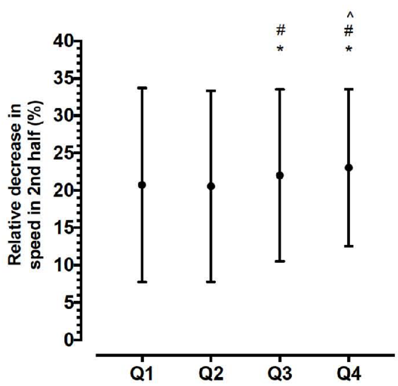
To perform these studies, we require the race results for the last 10 "up" and "down" races ie all the race results from 2002 to 2019. To calculate the change in pace as the race progresses, the split times for each runner at the various timing check points throughout the race will be needed, in addition to the finishing time of each runner. We only need the runner names in order to identify runners who have run more than one race during the time period being analyzed.

The results for each "up" run and each "down" run will be combined into a single spreadsheet, after which the results for the female and male runners will be extracted, leaving a complete list of results of all the female runners and all the male runners for the last 10 "up" races and last 10 "down" races. Once this has been done, the results will be divided into quartiles ie the fastest 25%, the next fastest 25%, the next, and finally the slowest 25%. The average pace for each quartile, for each "split" available will then be calculated. Statistical tests will compare the pacing profiles between the top 25%, 50%, 75%, and 100% of all the finishers. Below is an example of this from a similar analysis of the Two Oceans marathon:



In the above graphs, the data has been "normalized" to 100% for each runner. The top left graph (A) shows the change in speed for the fastest 25% of the field ie first quartile, for the splits from 28km, to 42km, 50km and finally the finish at 56km. The top right graph shows this for the 2nd quartile, graph "C" for the 3rd quartile, and finally the 4th quartile of finishers ie the last 25% of finishers (graph D). Although I have not shown it as an example here, another graph would show the comparison in a single graph of the fastest through to the slowest runners.

Next, we would analyse how speed changes in the race, as shown below in the example from Two Oceans:



The above graph shows that the fastest 50% of runners (Q1 and Q2) slow down similarly, but the runners in the slowest 50% (Q3 and Q4) of the race slow down relatively more.

As previously explained, we aim to do the above type of analysis for female and male runners in the "up" race, as well as the "down" race. Ultimately, we would eventually compare male and female differences, and "up" and "down" race differences.

Ethical and regulatory compliance

I and my supervisor (Professor Bosch) will ensure that all results are handled in accordance with South African Good Clinical Practice (GCP) requirements. Ethical approval has been granted from the University of Cape Town's, Health Sciences, Human Research Ethics Committee. The study will adhere to the principles of the Declaration of Helsinki (World Health Association, 2017) and adhere to the Protection of Personal Information (POPI) Act, No 4 of 2013, which promotes the protection of personal information by public and private bodies.

Confidentiality

Data will be stored in a password protected file on my laptop and that of my supervisor. Initially the names and surnames of the runners will be necessary to eliminate any runners who feature in more than one year. Once this has been done, runners' names and surnames are of no relevance and each runner included in the study will be allocated a number. If the study were to get published, all the participants data and individual names will remain anonymous.

Questions and contact details

Please do not hesitate to contact Prof Andrew Bosch (study supervisor) or I if you have any questions with regards to this study. The contact details are below.

Genine Manchip (MSc student investigator)	Genine@gmphysio.co.za	+27 84 461 9987
Prof Andrew Bosch (study supervisor)	Andrew.bosch@uct.ac.za	+27 21 6504578
UCT FHS Human Research Ethics Committee	hrecenquiries@uct.ac.za	+27214066338

Kind Regards

Genine Manchip

"OUR MISSION is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."

Appendix 2: HREC REF 287/2022

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room 45 E-52-E-Floor- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

23 May 2022

HREC REF: 287/2022

A/Prof A Bosch
Division of Physiological Sciences
Sports Science Institute, Newlands
Email: Andrew.bosch@uct.ac.za
Student: genine@gmphysio.co.za

Dear A/Prof Bosch

PROJECT TITLE : A COMPARISON OF THE PACING STRATEGIES ADOPTED BY ELITE VERSUS NON-ELITE MALE RUNNERS IN THE COMRADES MARATHON-
(MASTERS CANDIDATE-MRS GENINE MANCHIP)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19. Please refer to guidance letter dated 02 February 2022 on our website:
http://www.health.uct.ac.za/fhs/research/humanethics/forms

Approval is granted for one year until the 30 May 2023.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Mrs Genine Manchip will also be involved in this study.

Please quote the HREC REF 287/2022 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637. Institutional Review Board (IRB) number: IRB00001938 NHREC-registration number: REC-210208-007
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2020), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix 3: FHS016: Annual Progress Report/Renewal

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001637; IRB00001938) This serves as notification of annual approval, including any documentation described below.			
☐ Approved	Annual progress report	Approved until/next renewal date	30/05/24
☐ Not approved	See attached comments		
Signature Chairperson of the HREC/ Designee	[signature]	Date Signed	29/3/2023

Note: Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za.
Please clarify your plan for research-related activities during COVID-19 lockdown.
Please use the latest form found on our website:
http://www.health.uct.ac.za/fhs/research/humanethics/forms

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	28/03/2023		
HREC REF Number	287/2022	Current Ethics Approval was granted until	30/05/23
Protocol title	A comparison of the pacing profiles adopted by elite versus non-elite male runners in the Comrades Marathon		
Protocol number (if applicable)	1		
Are there any sub-studies linked to this study?	☐ Yes	x No	
If yes, could you please provide the HREC Reference number for all sub-studies? **Note:** A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Genine Manchip		
Department / Office Internal Mail Address	Supervisor: Prof Andrew Bosch Andrew.bosch@uct.ac.za		

HUMAN RESEARCH
ETHICS COMMITTEE
29 MAR 2023
HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN

28 February 2022 Page 1 of 7 FHS016

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)