

Pacing patterns of elite and non-elite male Two Oceans Marathon runners

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LIST OF ABBREVIATIONS

TOM	Two Oceans Marathon
UCT	University of Cape Town
CP	Checkpoint(s)
MRP	Mean Race Pace
Km	Kilometre
Mi	Miles
RPE	Rate of Perceived Exertion
GLMM	Generalised Linear Mixed Effects Model

GLOSSARY OF TERMS

Marathon: A long-distance running race; strictly 42.195 km (Nikolaidis and Knechtle, 2018).

Ultra-marathon: A long-distance running race exceeding the standard marathon distance of 42.195km or alternatively, a long-distance running race exceeding 4 hours in duration (Roebuck *et al.*, 2018).

Pacing pattern: Muscular work distributed throughout an exercise bout (Casado *et al.*, 2020).

Positive pacing: Faster initial speed (pace) through the first half of the race followed by progressive speed decrease in the second half of the race (Abbiss and Laursen, 2008).

Negative pacing: Slower initial speed (pace), through the first half of the race followed by speed increase in the second half of the race (Abbiss and Laursen, 2008).

Even pacing: Implementation of a constant race speed (pace) for the duration of the exercise bout (Abbiss and Laursen, 2008).

Parabolic shaped pacing: Combines both negative and positive pacing through different segments of the race (Abbiss and Laursen, 2008).

Teleoanticipation: An athlete's ability to perceive or anticipate the amount of work still required to complete a given exercise task (Bath *et al.*, 2012).

Thermoregulation: Thermoregulation is the process by which organisms maintain a stable internal body temperature despite fluctuations in external conditions, vital for overall health (Cheuvront and Haymes, 2001).

Fatigue: Fatigue is commonly described as a reduction in strength, specifically a decrease in maximal voluntary contraction, which varies depending on the nature of the physical activity performed (Millet, 2011).

Rate of Perceived Exertion: A subjective measurement scale used to measure an individual's perception of an exercise intensity (Matta *et al.*, 2020).

VO₂ max: The maximum amount of oxygen that an individual can utilise during intense or maximal exercise (Besson *et al.*, 2022).

End spurt: The end-spurt denotes athletes' inclination to intensify their effort, such as velocity or power output, as they approach the conclusion of a physical task, typically when the task is 95%complete (Tan, Tan and Bosch, 2016).

Hitting the wall: Refers to pre-mature fatigue. A term describing an unintentional, drastic, and continuous deceleration of an athlete's race pace due to fatigue (Doherty, Keogh, Smyth, *et al.*, 2020).

Running Economy: Represented by the energy demand for a given velocity of submaximal running and expressed as the submaximal VO_2 at a given running velocity (Barnes and Kilding, 2015).

ABSTRACT

Introduction: Limited information exists about the pacing patterns of elite and non-elite runners competing in the 56km Two Oceans Marathon.

Objective: The main aim of the study was to establish and compare similarities and differences in pacing patterns between elite and non-elite male runners in the Two Oceans Marathon.

Methods: Data was analysed from the Two Oceans Marathon database of finishers. Male participants across 10 races from 2007 – 2019 formed the sample group (N=25 315). The sample group was ordered fastest to slowest and subsequently divided into 8 groups (A-H) by merit of finishing times. Four timing segments (1-4) were recorded and used to calculate pace (in km/h) in each segment and mean race pace of each finisher. A Generalised Linear Mixed Effects Model (GLMM) analysis was used to examine the patterns of average pace change between groups.

Results: A reduction in average pace was observed across all groups for the first three segments, with an increase in average pace for the final segment ($p<0.0001$). Pairwise comparison of change in pace between mean race pace across all four segments demonstrated that elite runners start the race more conservatively when compared to non-elite runners ($p<0.0001$).

Conclusion: The findings demonstrated a parabolic type pacing pattern where elite runners demonstrated less pace variation, while non-elite runners displayed more pace variation. Non-elite runners completed the first half of the race substantially faster relative to their overall race pace. Results suggest that to achieve an optimal pacing pattern, non-elite runners should consider adopting a more realistic starting pace.

Key Words: Pacing pattern, pacing strategy, pacing profile, ultra-marathon, variability.

CHAPTER 1: Introduction and scope of thesis

1.1. INTRODUCTION

The 56km Two Oceans Marathon (TOM) had its inaugural race day on May 2, 1970, with a modest 26 participants (Two Oceans Marathon, 2021). Over the years, it has transformed into what has been termed the world's most beautiful marathon, attracting an estimated 11,000 participants in 2023 (Two Oceans Marathon, 2021).

This iconic event draws runners from around the globe, from novice enthusiasts to elite athletes (Two Oceans Marathon, 2021). The marathon course (Figure 1) is characterised by a relatively flat first half, followed by challenging elevation gains and losses in the second half, which features notable segments such as the scenic “Chapman's Peak Drive” and “Constantia Neck” (Two Oceans Marathon, 2021). The demanding second half culminates in an undulating final climb towards the finish line at the University of Cape Town (UCT) (Two Oceans Marathon, 2021). The TOM falls into the category of ultra-marathons, which is defined as events exceeding the traditional marathon distance of 42.195km (Millet, 2011; Knechtle *et al.*, 2015; Garbisu-Hualde and Santos-Concejero, 2020).

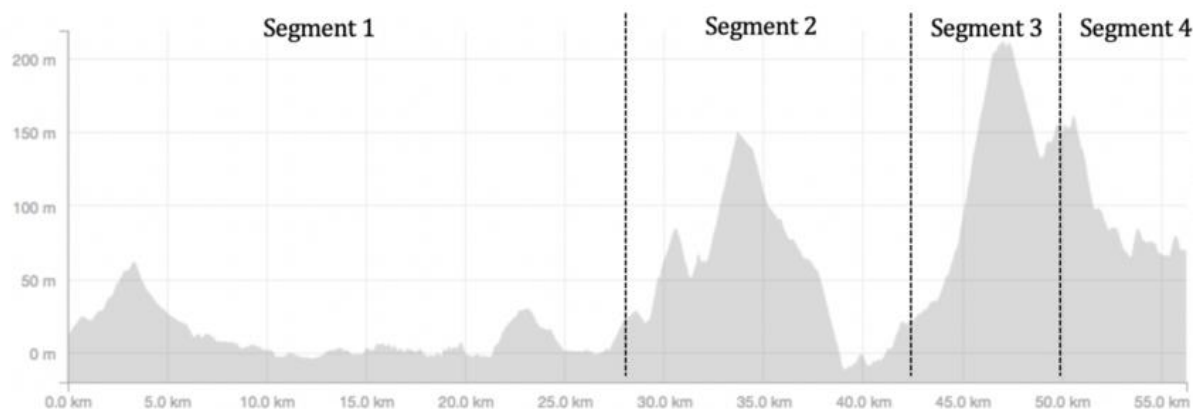


*Figure 1: Race profile of TOM, showing the timing points for each of the segments, as used in the data analysis of this study. Segment 1 incorporates the start to 28km, Segment 2 from 28-42km, Segment 3 from 42-50km and Segment 4 from 50-56km (Johansson *et al.*, 2020).*

In scientific literature, terms such as "Pacing," "Pacing profile," "Pacing strategy," and "Pacing pattern" have been used interchangeably to describe the deliberate distribution of exercise intensity throughout a race (Skorski and Abbiss, 2017). In simple terms, pacing refers to a pre-

planned, conscious decision made by a runner before and during a marathon race with respect to the speed and intensity at which the race is completed (Casado *et al.*, 2020).

Race strategies have undergone significant evolution over time, transitioning from traditional positive pacing, characterised by a faster first half, to the contemporary approach of negative pacing, favoured by elite marathoners (García-Manso *et al.*, 2021). This involves a slower first half, and progressively increasing speed, typically after the halfway mark, in the second half. Furthermore, elite marathoners strive to minimise pacing variability to achieve the fastest race finish, leading to the emergence of the so called “even pacing pattern” (Casado *et al.*, 2020; Doherty, Keogh, Smyth, *et al.*, 2020). However, the rationale for adopting an even pacing pattern draws from principles of motion physics, which propose that an athlete's velocity is governed by the maximum sustainable force they can exert (including factors such as power output), offset by resistive forces encountered during performance (such as wind, temperature, terrain, and race profile) (Abbiss and Laursen, 2008). Moreover, even pacing is commonly seen in shorter events with stable external conditions, such as track cycling. In contrast, marathon running presents varying challenges such as gradients and differing durations, making it highly challenging to maintain a consistent pace (Abbiss and Laursen, 2008). Consequently, contemporary elite marathon athletes often prefer a negative pacing strategy, which is considered optimal for marathons, particularly those with uphill segments. (Díaz, Fernández-Ozcorta and Santos-Concejero, 2018; Casado *et al.*, 2020; García-Manso *et al.*, 2021). In contrast, in ultra-endurance events lasting over 4 hours, elite athletes predominantly adopt positive pacing (Abbiss and Laursen, 2008; Knechtle *et al.*, 2015; Genitrini *et al.*, 2022). While elite marathoners strive for the fastest possible finishing time, non-elite runners often prioritise managing the physiological demands of the race and simply completing it (Nikolaidis and Knechtle, 2017).

1.2. STATEMENT OF THE PROBLEM

Long distance running, particularly marathon and ultra-marathon running, has seen a significant rise in popularity, on a global scale (da Fonseca-Engelhardt *et al.*, 2013; Cejka *et al.*, 2014; Vitti *et al.*, 2020) attracting participants of various ages, genders, and levels of experience (Alvero-Cruz *et al.*, 2020; Swain, Biggins and Gordon, 2020). Major marathons like those held in New York, Boston, Berlin, London, and the TOM draw thousands of participants. Despite extensive research analysing pacing patterns among elite and non-elite athletes in international marathons such as those mentioned, there is a noticeable gap in understanding pacing patterns within the context of the TOM.

Optimal pacing strategies for ultra-marathon events like the TOM are still uncertain. While even pacing has been suggested as an optimal strategy in marathons (on flat courses), longer distance events like ultra-marathons are influenced by a broad range of dynamic external influences (Lambert *et al.*, 2004; Tan, Tan and Bosch, 2016) as well as often being on hilly courses. Currently, no data is available on the pacing patterns of both elite and non-elite runners in the 56 km TOM footrace.

1.3. AIM AND OBJECTIVES

1.3.1. Aim

This study aims to analyse and compare the pacing patterns of elite and non-elite male runners who completed the TOM from 2007-2019.

1.3.2. Objectives

The specific objectives are:

- (1) To establish and compare pacing patterns of elite and non-elite male athletes that completed the TOM in the designated period.
- (2) To analyse and compare pace differences between elite athletes and non-elite athletes at each timed checkpoint (CP) of the TOM.
- (3) To analyse and compare starting pace differences on overall performance between elite and non-elite athletes by comparing starting speed to overall mean race pace (MRP).

1.3.3. Significance of the study

This study will provide insights into the pacing behaviours exhibited by runners of different abilities in the context of the TOM. This is particularly relevant for both runners and coaches, as it enables a deeper understanding of the relationship between initial, mid-race, and late-stage pace. This information will provide key information for runners on how to refine their pre-race preparations and planning pace strategy during the race.

1.4. STUDY OUTLINE

A review of the literature on pacing patterns and a range of factors influencing said patterns within marathon and ultra-marathon running events will be presented in Chapter 2. This is followed by the study methodology, results, and a discussion of the study findings that will be presented in Chapter 3. The summary and conclusion form Chapter 4.

CHAPTER 2: Literature Review

2.1. INTRODUCTION

2.1.1. Overview

Since becoming a recognised sport in the 1970's and 1980's (Roebuck *et al.*, 2018) long-distance running has increased in popularity during the last decade (Alvero-Cruz *et al.*, 2020), with marathon running now being one of the most participated in of endurance events worldwide (Muñoz-Pérez *et al.*, 2020) for people of both sexes, various ages, and different participation levels (Doherty, Keogh, Smyth, *et al.*, 2020). This is highlighted by the fact that on average 470 000 people completed a marathon between 2004 and 2016 in the United-States of America (Doherty, Keogh, Smyth, *et al.*, 2020), and 133 552 people finished the Comrades Marathon between 2010-2019 (Comrades.com, n.d.). Popular international city marathons such as the New York, Boston, Berlin, and London, as well as the local ultra-marathons such as Comrade Marathon and TOM, attract thousands of runners.

The research literature extensively examines pacing strategies among elite athletes in international marathons, yet there has been no analysis of pacing at the TOM. Optimal pacing strategies for ultra-marathon events, in general, remains unclear. While even pacing has been proposed as an optimal pacing strategy in the standard marathon, longer distance events are subject to larger dynamic external influences and the ideal pacing pattern remains unclear (Tan, Tan and Bosch, 2016).

Currently, limited data is available on the pacing patterns of elite and non-elite runners competing in the 56km TOM race. This study aims to analyse the pacing patterns of the elite runners competing in the TOM and to compare these with the pacing patterns of non-elite runners ranging from sub-elite to social runners.

2.1.2. Review Methodology

The literature review will outline pacing patterns and enumerate the various factors that define and influence pacing patterns.

Several electronic databases, accessed through the University of Cape Town library, were searched for relevant literature pertaining to the topic of pacing in marathon and ultra-marathon running. The searched databases included PubMed, ScienceDirect, Google scholar and Cochrane Library. Where required, additional literature was obtained through manual searches, and cross-referencing of the articles selected in the mentioned databases.

Relevant search terms used in the search engine were: "Pacing" OR "Pacing strategy" OR "Pacing Profile" OR "Pacing Pattern"; "Marathon" OR "Ultra-marathon"; "Male runner(s)"; "Variability"; "Performance".

2.2. BACKGROUND

2.2.1. History of long-distance running

The modern Olympic marathon traces its origins to the legendary tale of Pheidippides in 490 BC (Jones, 2003). According to this story, Pheidippides, a professional messenger, ran approximately 25 miles (40.2336 km) from Marathon to Athens to deliver news of a crucial Greek victory over the Persian Army, and tragically died upon completing his mission (Jones, 2003). Competitive running itself has deep historical roots, with one of the earliest recorded instances dating back to 1829 BCE at the Tailteann Games in Ireland, an ancient festival associated with the goddess Tailtiu (Matthews, 2012). In 1907, the International Olympic Committee decided that the marathon distance for the 1908 London Olympics would be approximately 40 kilometres. The race organisers chose a route starting at Windsor Castle and ending at the royal entrance to White City Stadium where the runners would then complete a lap around the track, finishing in front of the Royal Box (Polley, 2009). The International Amateur Athletic Federation formally standardised the current marathon distance of 42.195 kilometres in May 1921, adopting the length used during the 1908 Summer Olympics in London (World Athletics, 2021).

However, it was not until the 1970s and 1980s that running began to gain widespread popularity (Roebuck *et al.*, 2018). The world's first running club was established by coach Arthur Lydiard (Figure 2) in Auckland, New Zealand, in 1961 (Lathan, 2023). In 1962, American track coach Bill Bowerman visited New Zealand, where he encountered Lydiard's innovative training methods focused on running as a fitness routine, subsequently bringing these ideas back to the United States (Lathan, 2023). During the 1970s, running surged in popularity, primarily as a recreational and fitness pursuit, with competitive road races gaining momentum throughout the decade (Lathan, 2023). An estimated 25 million Americans participated in running during this period, including then-President Jimmy Carter (Lathan, 2023).

2.2.2. Background of Ultra-Marathon Running

Ultra-marathons are broadly defined as events surpassing the traditional marathon distance of 42.195km (Millet, 2011; Knechtle *et al.*, 2015; Garbisu-Hualde and Santos-Concejero, 2020).



Figure 2: Arthur Lydiard, March 1949 (Pankaj, 2020)

Furthermore, time-limited ultra-marathons typically range from 6hours, 12hours, 24hours and 48hours and distances of 50km (31.1mi), 80.5km (50mi), 100km (62.1mi), and 161km (100mi) respectively (Roebuck *et al.*, 2018). Therefore, the TOM is classified as an ultra-marathon.

2.2.3. The Two Oceans Marathon: History

The TOM, proclaimed as the world's most beautiful marathon by the organisers, held its inaugural race in 1970 with just 26 participants (Two Oceans Marathon, 2021). Since then, it has grown into an international event, annually contributing approximately R672 million to the economy of the area, being one of South Africa's largest running events in terms of economic impact (Two Oceans Marathon, 2021). The event has become synonymous with Easter Weekend in Cape Town, South Africa, featuring pre-race activities at the expo, fun runs on Easter Friday, and on-course entertainment such as live music on race day, catering to families and offering something for everyone (Two Oceans Marathon, 2021).

2.2.4. The Two Oceans Marathon: Route

The TOM is a 56km road race held in Cape Town, South Africa. The route comprises of a first half of relatively flat tarred road, followed by a mountain pass, a brief flat section, and then a significant climb, before the last 10km comprising of a significant amount of downhill running. There is a cumulative vertical gain of approximately 800m (Johansson *et al.*, 2020), but the finish is only slightly higher in altitude than the start. To compete in the TOM an entrant must complete a qualifying marathon in a specified time (42.2km in sub 5:00 hours) or longer distance (50km in sub 6:30 hours) (Two Oceans Marathon, 2021.).



Figure 3: 2023 TOM route and elevation (X (formerly Twitter), 2024)

2.3. PACING PATTERNS

2.3.1. Definition of pacing

Pacing is the strategic management of muscular effort over the course of an exercise session (Renfree *et al.*, 2015; Casado *et al.*, 2020; Muñoz-Pérez *et al.*, 2023). Athletes often plan their pacing strategies before an event begins, anticipating how they will distribute their energy resources (most of the runners “just go and run”). Once the event is underway, pace is often adjusted in response to their physical condition, feelings of fatigue and the tactics of competitors (Casado *et al.*, 2020; Muñoz-Pérez *et al.*, 2023). This dynamic decision-making process starts well before the event starts and continues throughout its duration until completion (Renfree *et al.*, 2015).

In other words, pacing refers to how quickly or slowly athletes move through an activity (Abbiss and Laursen, 2008). It's crucial to note that pacing, in this context, specifically refers to the timing of performance—how quickly an athlete completes a task or covers a distance—rather than the physical work or power they generate during that time (Abbiss and Laursen, 2008).

2.3.2. Importance of pacing

Pacing is widely recognised as a critical factor influencing performance outcomes in endurance sports (Renfree, Crivoi do Carmo and Martin, 2016; Díaz, Fernández-Ozcorta and Santos-Concejero, 2018; Smyth, 2018; Doherty, Keogh, Davenport, *et al.*, 2020). The primary objective of pacing strategies is to enable runners to conserve sufficient energy reserves to successfully complete a race in accordance with their individual pre-race goals (Renfree *et al.*, 2015). Therefore, athletes participating in endurance events must continuously adjust their speed and effort levels throughout the competition. This adaptive approach is essential for optimising performance and achieving the fastest possible race completion time (Abbiss and Laursen, 2008; Skorski and Abbiss, 2017).

2.3.3. Pacing patterns

Traditionally, in athletic performance, three pacing patterns have been identified namely positive, negative, and even pacing (Foster *et al.*, 1994; Tan, Tan and Bosch, 2016). Recent studies have however identified six pacing patterns (Figure 4) as follows (Abbiss and Laursen, 2008; Nikolaidis and Knechtle, 2017):

1. **Positive pacing:** Faster initial speed (pace) through the first half of the race followed by speed decreases in the second half of the race due to onset of fatigue.
2. **Negative pacing:** Slower initial speed (pace) through the first half of the race followed by speed increase over the second half of the race.

3. **All-out pacing:** Maximum race speed throughout race. Mainly observed over shorter distances.
4. **Even pacing:** Implementation of a constant race speed (pace) for the duration of the exercise bout.
5. **Parabolic-shaped pacing:** Combines both negative and positive pacing through different segments of the race.
6. **Variable pacing:** Multiple speed fluxes throughout the exercise bout.

It is important to note that (this research done by Abbiss and Laursen (2008) these profiles were initially developed using analyses that primarily concentrated on swimming, cycling, and rowing. Understandably, research on running was significantly lacking because detailed, official performance data from major global track events (such as 800 m, 1500 m, 5000 m, and 10,000 m races) were rarely available for study before 2008 (Casado *et al.*, 2020).

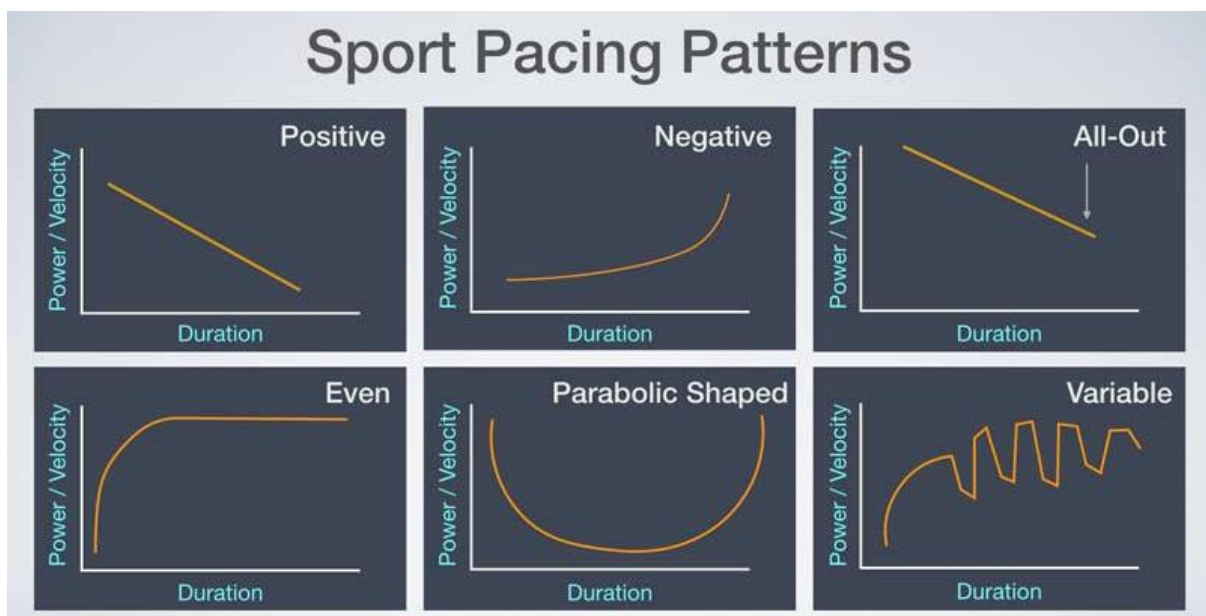


Figure 4: Pacing patterns (Valle, 2020)

2.3.4. Pacing strategies of ultra-marathon runners

Lambert *et al.* (2004) conducted an analysis of race times among ultra-marathon runners participating in the 100km International Association of Ultrarunners world challenge to examine variations in running speeds and differences in pacing patterns between faster and slower runners. Their findings indicated that elite runners' finishing speeds were within 15% of their starting speeds, which suggests that elite runners, despite slowing as the race progressed, were able to maintain speeds close to their initial pace. In contrast, non-elite runners were

unable to do so and exhibited greater variability in speed throughout the race (Lambert *et al.*, 2004). This suggests that faster athletes tend to regulate their pace more tightly compared to slower athletes. Additional studies have supported these observations, showing that top-performing 100km ultra-marathon athletes often maintain a high percentage of their starting speed throughout the race (Knechtle *et al.*, 2015; Tan, Tan and Bosch, 2016). Moreover, Parise and Hoffman (2011) identified a common reverse J-shaped pacing pattern (Figure 5) among all athletes, regardless of their finishing times (Parise and Hoffman, 2011). Further research by Tan, Tan, and Bosch (2016) highlighted several key points: 1) Pacing strategies during 161km and 101km ultra-marathon races remained consistent across performance groups; 2) Elite runners tend to mimic the pacing of those ahead of them, while slower runners form smaller groups based on current speed; 3) Faster athletes exhibit less variability in their running speeds; and 4) Runners adopt a more conservative approach to finishing their races when faced with uncertainty about their ability to complete the remaining distance (Tan, Tan and Bosch, 2016).

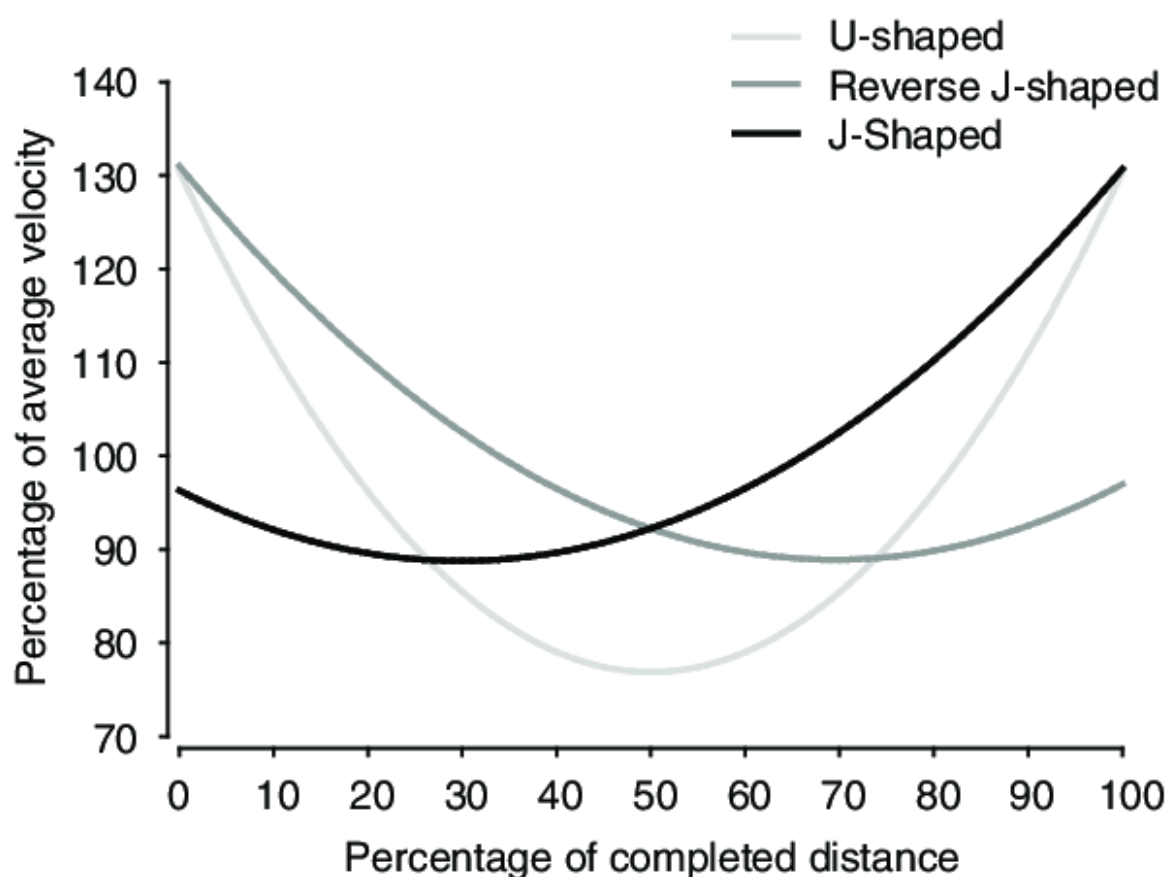


Figure 5: Parabolic shaped pacing patterns (Abbiss and Laursen, 2008)

2.4. FACTORS INFLUENCING PACING

Marathon running stands as a testament to human endurance and physiological capability (Knechtle *et al.*, 2018). Performance in marathons is influenced by a multitude of factors (Roebuck *et al.*, 2018; Besson *et al.*, 2022). Understanding these factors assist athletes, coaches, and researchers to enhance training methods and achieve better race results (Solli, Tønnessen and Sandbakk, 2017).

Influential factors discussed below can be categorised as external factors (distance, course gradient, and temperature), athlete profile factors (age, gender, and ethnicity), and internal factors (thermoregulation, fatigue, rate of perceived exertion, and teleoanticipation).

2.4.1. Distance

Casado *et al.* (2020) provide an overview of pacing strategies across various distances. In sprint events such as the 100m or 200m, athletes typically employ an "all-out" strategy characterised by a high initial acceleration cost. For 400m and 800m races, a positive pacing pattern is commonly observed. In longer distances like the mile and 1500m, a parabolic U-shaped pacing strategy is prevalent, with major championship 1500m races exhibiting a parabolic J-shaped profile characterised by a fast start followed by slowing of pace before and end spurt. Similarly, 3000m, 5000m, and 10000m races generally follow a parabolic U-shaped pacing strategy, albeit with increased microvariations in pace during major championship events. Cross-country runners tend to adopt a positive pacing strategy, whereas half marathoners typically display a parabolic U-shaped profile (Casado *et al.*, 2020). Renfree and Gibson (2013) found that among the top 25% of finishers in the World Marathon Championships 2009, an even pacing strategy was most common. However, most marathon runners—approximately 95% of males and 87% of females—exhibit a positive pacing strategy, where the second half of the marathon is run at a slower pace (Hettinga, Edwards and Hanley, 2019).

2.4.2. Course gradient

It is important to note that numerous variables such as course gradient must be considered when analysing pacing strategies as these can greatly affect the pacing patterns. (Casado *et al.*, 2020). In contrast to the even pacing strategy adopted at the World Marathon Championships, top finishing athletes taking part in the New York Marathon generally adopt a negative pacing pattern due to the uphill early in the race and the downhill towards the end of the race (Díaz, Renfree, *et al.*, 2019). Whereas winning performances in the Berlin Marathon adopted a more even pacing pattern due to the mostly flat course profile (Díaz, Renfree, *et al.*, 2019).

2.4.3. Age

Age is considered an important predictor of running performance in marathon and ultra-marathon runners (Knechtle *et al.*, 2010; March *et al.*, 2011; Rüst *et al.*, 2015). Successful ultra-marathon runners are aged 35 years or older (Hoffman, Ong and Wang, 2010; Knechtle *et al.*, 2014) and the mean ultra-marathon runner age is 45 years (Rüst *et al.*, 2015). This data is further substantiated by researchers that investigated peak performance trends in the Comrades Marathon who found the age of 35 to be the peak performance age of both male and female runners (Knechtle and Nikolaidis, 2017). Similarly, between 1998 and 2011, the average age of the top ten annual finishers in 161km ultra-marathons were approximately 39.2 years for women and 37.2 years for men (Rüst *et al.*, 2013).

Furthermore, Knechtle *et al.*, (2014) hypothesised that peak performance age in ultra-marathon running increase with increasing event distance or duration and showed that the lowest age of peak performance was 33.7 years for 6hour timed endurance events, and the highest age was 46.8 years for 48hour events (Knechtle *et al.*, 2014). This increase in peak age as distance increase is likely due to athlete experience, such as the number of races completed and personal best times. These variables have been reported as important predictors in ultra-marathons (Knechtle *et al.*, 2014; Hoffman and Parise, 2015). Additionally, these ultra-runners typically had seven years of regular running experience before attempting their first ultra-marathon which subsequently means that they became ultra-marathon runners at a more advanced age (Knechtle *et al.*, 2014). Many athletes only turn to the ultra-marathon racing after they have completed many standard marathons, or when they have stopped improving over the standard marathon distance, and then decide to proceed to ultra-marathons. This inevitably implies an older age at the time that these athletes decide to move on to ultra-marathon races.

An analysis of male and female runners participating in the New York City marathon between 2006-2016 by Nikolaidis and Knechtle (2017) revealed a significant interaction between age and performance level in pacing. Younger age groups exhibited greater changes in speed during the race compared to older age groups, and this pattern was more evident in runners with slower race times (Nikolaidis and Knechtle, 2017). In contrast, a study which analysed changes in running speed by 5km splits during the 2015 New York City marathon found no significant difference in pacing between split and age group interaction (Nikolaidis and Knechtle, 2018). Likewise, in the World Masters Championships for 100km ultra-marathoners, pacing was consistent across all age groups (Renfree, Crivoi do Carmo and Martin, 2016).

In the analysis of TOM race times, no differentiation with regards to age have been made.

2.4.4. Gender

Research comparing pacing strategies between male and female world record marathon performances from 1998 to 2018 reveals distinct patterns. Women typically favour an even pacing strategy, whereas men more frequently exhibit a negative pacing strategy (Díaz, Fernández-Ozcorta, *et al.*, 2019). Additionally, female marathoners are noted for their more consistent pacing and lower running speed variability compared to their male counterparts in similar events (March *et al.*, 2011; Renfree, Crivoi do Carmo and Martin, 2016; Cuk, Nikolaidis and Knechtle, 2020). These differences between sexes are attributed to physiological variations (Besson *et al.*, 2022) and differences in decision-making tendencies (Smyth, 2018). Recent studies have underscored several psychological factors influencing marathon pacing, with risk-taking behaviour identified as a significant predictor of pace decline (Deaner, Addona and Hanley, 2019). Men, in particular, tend to adopt a more aggressive pacing strategy, initiating the race at a faster pace relative to their capabilities, which increases the likelihood of fatigue and performance decline later in the race (Cuk, Nikolaidis and Knechtle, 2020). This tendency suggests that male runners may sometimes overestimate their abilities, whereas female runners tend to pace more conservatively (de Koning *et al.*, 2011; Hubble and Zhao, 2016; Smyth, 2018).

2.4.5. Ethnicity

East African athletes have consistently shown their dominance in modern major marathons, characterised by their adeptness in employing negative to even pacing patterns (Casado *et al.*, 2020). These remarkable performances are often attributed not only to physiological and anatomical factors but also to their rigorous training regimes, which involve substantial volumes of training conducted at or near marathon race pace (Casado *et al.*, 2020). This training approach is believed to finely tune their ability to sustain competitive speeds over the marathon distance, contributing significantly to their competitive edge on the global stage.

2.4.6. Thermoregulation and temperature

Efficient thermoregulation, the ability to maintain core body temperature, is critical during marathons, particularly in hot conditions, as inadequate thermoregulation can result in heat stress and dehydration, impairing performance (Cheuvront and Haymes, 2001). Studies have shown that running speed tends to be more consistent in cooler weather compared to warmer conditions (Ely *et al.*, 2008). For instance, in a 161km trail ultra-marathon, runners across all performance levels demonstrated pace variations due to warmer temperatures, with all participants slowing their pace by 35-45 seconds per kilometre in a warmer year compared to a cooler year (Parise and Hoffman, 2011). Similarly, participants running submaximal 8km trails in hot conditions (35°C) adjusted their pacing to ensure completion of the exercise, albeit

at a slower speed compared to trials conducted in cooler temperatures (15°C) (Marino, Lambert and Noakes, 2004). Researchers suggest that runners modify their pace in anticipation of rising temperatures (Parise and Hoffman, 2011).

2.4.7. Fatigue

Human fatigue encompasses both performance fatigability, which is the measurable decline in endurance over time, and perceived fatigability, which relates to changes in how individuals perceive their physiological and psychological state (Venhorst, Micklewright and Noakes, 2018). This fatigue manifests as an inability to sustain a desired velocity during exercise (Tan, Tan and Bosch, 2016). It has been suggested that during a 100 km race, runners typically utilise around 65% of their VO_2 max. However, significant differences in resistance to fatigue and running economy contribute to varying levels of performance among athletes (Lambert *et al.*, 2004). Additionally, neuromuscular fatigue resulting from repeated eccentric muscle actions can impair muscle function and contribute to reduced speed (Lambert *et al.*, 2004; Millet, 2011).

Poor pacing strategies can exacerbate physiological strain (depleting muscle glycogen), leading to unsustainable power outputs and the phenomenon known as "hitting the wall", where a runner experiences a sudden and prolonged decline in pace (Doherty, Keogh, Smyth, *et al.*, 2020; Smyth, 2021). Premature fatigue poses a significant threat to performance, prompting runners to employ optimal pacing strategies to mitigate its effects (Buman *et al.*, 2008; Millet, 2011; Díaz, Fernández-Ozcorta and Santos-Concejero, 2018).

Research indicates that adopting a positive pacing strategy initially increases oxygen consumption and the accumulation of fatigue-related metabolites, prompting athletes to adjust their intensity to maintain homeostasis, thereby adopting a positive pacing profile (Tan, Tan and Bosch, 2016). Conversely, a negative pacing strategy enhances endurance performance by optimising carbohydrate metabolism and reducing oxygen consumption early in a race (Tan, Tan and Bosch, 2016). Highly trained endurance athletes often utilise an even pacing strategy to sustain submaximal exercise intensity consistently throughout an event (Tan, Tan and Bosch, 2016).

2.4.8. Rating of Perceived Exertion

The Rating of Perceived Exertion (RPE) scale (Figure 6) serves as both an intensity marker and an indicator of homeostatic disruption during exercise (Eston, 2012). Its psychophysiological significance is considerable, as evidenced by its diverse applications in predicting exercise capacity, tracking changes during training, and elucidating variations in pacing strategies (Eston, 2012). Studies have demonstrated that as exercise progresses towards exhaustion, increases in RPE correlate directly with the remaining duration,

Rating Perceived Exertion Scale		Zones	Training Examples
RPE 1	Easy	Active Recovery	Barely doing much of anything...
RPE 2			All day pace, very easy rides, walks, house hold chores.
RPE 3	Moderate	Aerobic Building	Long steady aerobic building, bodyweight practice, steady walking, hiking, comfortable running, etc. Working on moving efficiently and breathing.
RPE 4			
RPE 5	Hard	Tempo	Hiking moderate to difficult terrain, tempo riding, strength & conditioning workout, trail run, challenging yard work.
RPE 6			
RPE 7	Difficult	Threshold	Max sustainable 60 minute effort, then you fall over. Can be 20 - 30 minutes max efforts held at a consistent pace. Difficult strength workout.
RPE 8		Vo2 Max	3 - 8 minute all out efforts, then you fall over and may not breathe normally for a few minutes. Intense strength & conditioning circuit.
RPE 9	Maximum	Anaerobic Capacity	Strength & Power Training, 30 seconds to 2 minute max efforts cycling or running.
RPE 10		Neuromuscular Power	Max Lifts, Sprinting 10 seconds or under. Giving it everything you have for short distances or time.

Figure 6: Rating of perceived exertion scale (Mountain Peak Fitness, n.d.)

suggesting that the brain regulates both RPE and performance in anticipation of metabolic reserves and the anticipated endpoint (Eston, 2012). Adjustments in pacing can therefore be attributed, in part, to an internal assessment where current RPE is compared with a pre-planned "ideal rate of RPE progression," considering the distance yet to be covered (Eston, 2012). Consequently, RPE stands out as a valuable tool (Figure 6) for runners in guiding their pacing strategies effectively.

2.4.9. Teleoanticipation

Early in an exercise session, setting the pace involves estimating the effort needed, considering factors such as distance, course gradient, environmental conditions, runnability (technical difficulty), and the runner's training status (Millet, 2011). Seasoned athletes draw upon established patterns of power output developed through experience to maintain consistent effort levels throughout their performance (Baron *et al.*, 2011; Nikolaidis and Knechtle, 2018). This ability to anticipate and manage exertion levels and remaining workload during exercise is termed Teleoanticipation (Millet, 2011; Bath *et al.*, 2012; Nikolaidis and Knechtle, 2018). Teleoanticipation involves a delicate balance between sensing fatigue and

accurately gauging the demands still ahead in the exercise session (Abbiss and Laursen, 2008; Tan, Tan and Bosch, 2016; Konings and Hettinga, 2018).

In competitive racing events, athletes strive for a steady power profile that supports maintaining an optimal average speed throughout the race (Angus, 2014). Effective pacing strategies are crucial, as poorly managed efforts inevitably lead to slower finishing times and suboptimal performance outcomes across all levels of competition (Casado *et al.*, 2020). Analysis of pacing behaviours among runners in major marathons reveals that elite athletes exhibit more consistent pace regulation compared to recreational runners, who typically show greater variability (Haney and Mercer, 2011; Nikolaidis and Knechtle, 2017; Díaz, Fernández-Ozcorta and Santos-Concejero, 2018). Modern elite marathoners emphasise minimising pace variability to achieve the fastest possible race times, often resulting in the adoption of even pacing profiles (Casado *et al.*, 2020; Doherty, Keogh, Smyth, *et al.*, 2020; Oficial-Casado *et al.*, 2020).

2.5. SUMMARY

Current scientific literature clearly identifies a variety of pacing patterns adopted by runners of varying ability in athletic competition (Foster *et al.*, 1994; Abbiss and Laursen, 2008). By minimising variability of pace changes, runners ensure optimal energy expenditure, preventing premature fatigue and optimising race performance (Renfree *et al.*, 2015; Nikolaidis and Knechtle, 2017, 2018; Casado *et al.*, 2020; Oficial-Casado *et al.*, 2020; Muñoz-Pérez *et al.*, 2023).

However, strong finishes may be linked to overly cautious initial pacing patterns during the initial stages of an event, suggesting—possible flawed pacing strategies (Smyth, 2021). Therefore, understanding the negative impact of starting too fast may be a means to improved mid-race pacing and a faster finishing time (Smyth, 2018).

CHAPTER 3: Pacing patterns of elite and non-elite male Two Oceans Marathon runners

3.1. INTRODUCTION

The TOM takes place around mid-April in Cape Town, South Africa. The 56km ultra-marathon is a circular route, of which the first 28km can be regarded as flat. After 28km the route climbs and descends “Chapman’s Peak Drive” in Hout Bay, climbs again from the standard marathon mark (42.2km) to 46km, before a series of predominantly downhill undulations, and finishing at the University of Cape Town sports field. The race typically starts at 05h10am with runners divided into starting batches consisting of approximately 1000 runners per batch (men and women), with the final batch estimated to start at 05h32am. Runners are allotted 7 hours (gun to mat) to complete the race.

3.2. METHODOLOGY

3.2.1. Study design

This descriptive study of TOM male finishers encompasses the TOM from 2007-2019, using race results publicly available on the official TOM website (Two Oceans Marathon, 2021). Four timed CP throughout the race were assigned as Segment 1-4. Segment 1 is from 0-28km, Segment 2 from 28-42km, Segment 3 from 42-50km, and Segment 4 is from 50-56km (finish). Timed CP were controlled by an independent timing company.

3.2.2. Participants

To increase the sample size, TOM timing results over 10 years were included in the dataset which included results from 2007, 2008, 2010 to 2014, and 2016 to 2018. The years 2009, 2015, and 2019 were excluded due to a different route being used and 2020 and 2021 were excluded due to race cancellation because of the Covid-19 pandemic. Race timing prior to 2007 did not include as many intermediate time points and were therefore excluded. In keeping with the analysis to be performed, the final dataset consisted of male only race participants who finished the TOM during the above mentioned 10-year period. Specifically, the results of all runners from the 10 years’ timing data were collated into a single Microsoft Excel spreadsheet for further analysis.

Female participants were removed as this study specifically investigated male runners; runners with missing timing CP were also excluded. Using the names of runners, we identified those who had completed the race more than once, and for statistical reasons these duplicate results

were removed from the dataset – leaving only their single fastest finishing time. Runners were then anonymised and assigned a specific participant code. The entire database was then ranked in descending order from fastest to slowest finishing time.

To determine the influence of performance level on the pacing pattern, the database of runners was divided into 8 groups A-H (Table 3) based on finishing time. Group A was classified as the elite group in this study (by their completion of the TOM in under 3h30min.

3.2.3. The following summarises the data preparation

Step 1: Appended "Two Oceans Marathon Results.xlsx" files from Year 2007 to 2018' (Note years 2009, 2015, 2019 are excluded due to a different route being used and 2020 and 2021 are excluded due to race cancellation because of the Covid-19 pandemic) this resulted in 97,834 runners.

Step 2: Using the "Status" Column in the data set the following statuses (Table 1) were filtered out leaving 77,276 runners:

Table 1: Runners' status being excluded from data analysis.

Status	# of Runners
After cut-off	1,661
Did not finish	4,132
Did not start	14,595
Disqualified	170
Total excluded	20,558

Step 3: Using the "Gender" Column in the data set all the females were filtered out (Table 2) leaving 57,062 runners:

Table 2: Number of male and female runners.

Status	# of Runners
Female	20,214
Male	57,062

Step 4: All rows with missing timing data in columns "Segment 2", "Segment 3", "Segment 4", and "Finish Time" were removed leaving 55,785 runners. Segment 1 referred to the segment from the start to 16km that is. 0-16km, which was subsequently omitted because this segment

was only included in a few of the races and was therefore excluded. Thus, Segment 1 became the distance from the start to 28km, Segment 2 was 28–42km, Segment 3 was 42-50km, and Segment 4 was 50-56km.

Step 5: Finally, using demographic information (name & surname, date of birth) only the fastest finish time per runner was kept, thus removing all duplicate entries of the same runner, leaving a final of 25,315 runners.

Step 6: Runners were anonymised with each data row renamed “runner” and ranked in chronological order from fastest finish time to slowest (i.e. Runner 1, Runner 2, Runner 3 etc.).

Step 7: Runners were then divided into groups (Table 3).

Table 3: Designated pacing groups

GROUP	TIME	NUMBER OF RUNNERS
A (Elite)	03h00-03h29min59sec	172
B	03h30-03h59min59sec	725
C	04h00-04h29min59sec	1414
D	04h30-04h59min59sec	3320
E	05h00-05h29min59sec	3899
F	05h30-05h59min59sec	6325
G	06h00-06h29min59sec	4543
H	06h30-07h00	4907

3.2.4. Statistical Analysis

The Generalised Linear Mixed Effects Model (GLMM) was employed to ascertain if a statistically significant difference existed in the pacing profiles across the eight groups of runners. The response variable, pace (expressed in km/h), is a continuous measure collected at four different timed CP (28km, 42km, 50km, and 56km), for each participant. Table 4 shows the average pace (in km/h) per segment for each group (Groups A to H).

To accommodate the intra-subject correlation resulting from repeated measures, a subject-specific random effect was integrated into the model. To identify significant differences among the average paces within each group (Table 5) as well as between group A and progressively slower groups (Table 6), we performed pairwise comparisons. These tables containing the results include the estimated values, standard errors, degrees of freedom, t-ratios, and p-values for each of the pairwise comparisons. The t-ratio column represents the

t-statistic calculated by dividing the estimate by the standard error. The higher the absolute value of the t-ratio, the more significant the difference between the segments. The p-value column displays the p-value associated with the t-ratio, indicating the probability of observing such a difference by chance. The Bonferroni correction was used to minimise the risk of false positives due to the multiple pairwise comparisons. This method adjusts the p-values by dividing the significance threshold (0.05) by the total number of comparisons. Furthermore, post-hoc tests employing the Tukey method were conducted to assess whether the observed differences between groups were statistically significant.

3.2.5. Ethical considerations

Ethical approval for this study was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (Appendix I: Ethics Approval Letter, and Annual Progress Report). All data used in this study is publicly available online at the official TOM website (<https://www.twooceansmarathon.org.za>).

3.3. RESULTS

3.3.1. Pacing profile displayed within each group.

Pacing patterns were similar across all groups (Figure 7). Notably, all groups showed an initial slow down between Segments 1-3, followed by a speed increase in Segment 4 (50-56km).

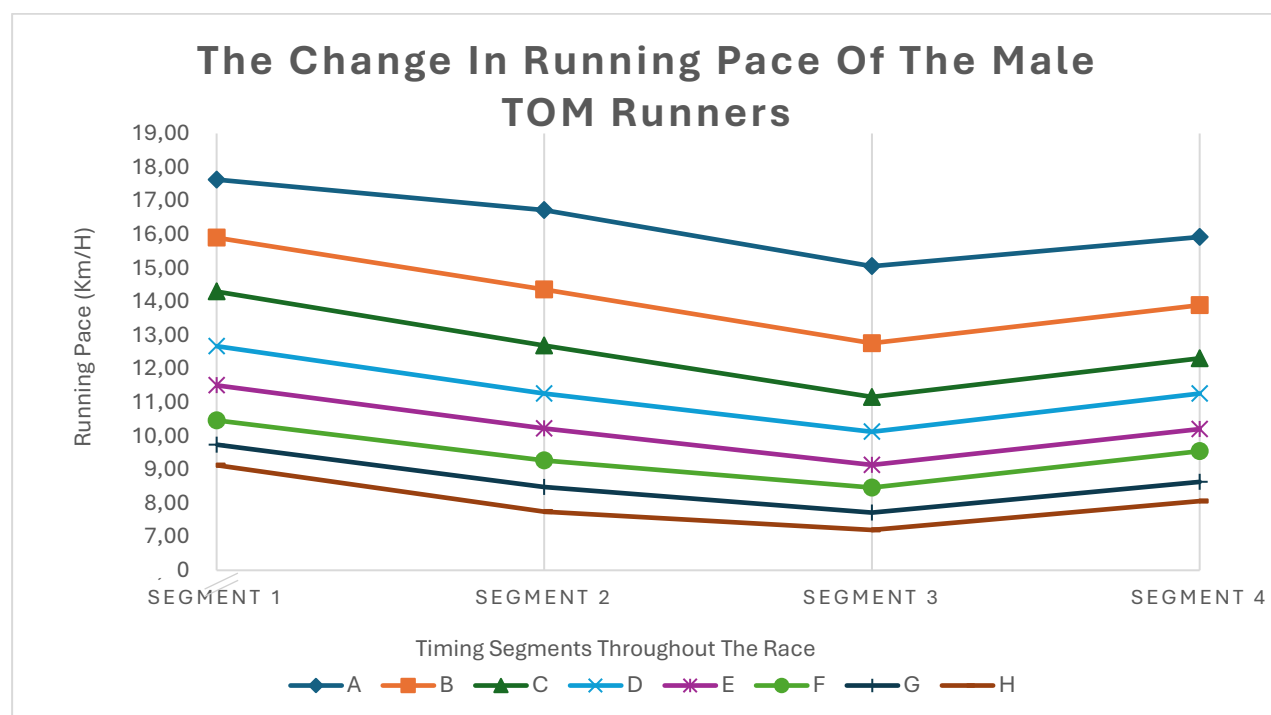


Figure 7: The change in running pace (km/h) for each group (A-H) over the time segments of the TOM route

Table 4 displays the average running speed for each group over the four segments of the race. Group A displayed the fastest average speed across all segments, achieving an overall peak running speed of 17.63km/h (CI= 17.52 - 17.73) in Segment 1 (0-28 km) of the race. Group A was followed by Groups B, C, D, E, F, G, and H in descending order. This is to be expected because the runners were divided into groups based on progressively slower race time.

Table 4: Mean pace (km/h) per segment (1-4) for each group (A-H). SE = Standard Error; DF= Degree of freedom; CL = Confidence Level.

Group & Segment	Mean pace (km/h)	SE	DF	Lower CL	Upper CL
A1	17.627	0.054367	101186	17.520	17.733
A2	16.720			16.613	16.826
A3	15.049			14.942	15.155
A4	15.920			15.814	16.027
B1	15.940	0.026481	101186	15.888	5.992
B2	14.350			14.298	14.402
B3	12.704			12.652	12.756
B4	13.837			13.785	13.889
C1	14.344	0.018962	101186	14.307	14.381
C2	12.696			12.659	12.733
C3	11.110			11.073	11.147
C4	12.247			12.210	12.284
D1	12.741	0.012375	101186	12.717	12.765
D2	11.262			11.238	11.287
D3	10.053			10.029	10.078
D4	11.192			11.168	11.217
E1	11.608	0.011419	101186	11.585	11.630
E2	10.220			10.198	10.243
E3	9.035			9.013	9.058
E4	10.082			10.060	10.105
F1	10.563	0.008965	101186	10.546	10.581
F2	9.254			9.237	9.272
F3	8.348			8.330	8.365
F4	9.424			9.407	9.442
G1	9.857	0.010579	101186	9.836	9.877
G2	8.463			8.442	8.484
G3	7.603			7.583	7.624
G4	8.485			8.465	8.506
H1	9.239	0.010179	101186	9.219	9.259
H2	7.710			7.690	7.729
H3	7.096			7.076	7.116
H4	7.925			7.905	7.945

3.3.2. Pacing profile per segment within each group.

Pairwise comparisons showed that Group A had the smallest decline in pace from Segment 1 – 2 (0.91 km/h $\pm$ 0.0769 km/h) while Group C had the largest (1.6 km/h $\pm$ 0.0268 km/h) (Table 5). In contrast to Segment 1 – 2, Group A showed the largest reduction in pace for segment 2

– 3 (1.67 km/h $\pm$ 0.0769 km/h) relative to their Segment 1 pace, closely followed by Groups B (1.65 km/h $\pm$ 0.0374 km/h) and C (1.57 km/h $\pm$ 0.0268 km/h) with Group H (0.61 km/h $\pm$ 0.0144 km/h) showing the least amount of slowing in Segment 2 – 3. ($p < 0.0001$). Group H (0.82929 $\pm$ 0.0144 km/h) showed the smallest increase in pace from Segment 3 – 4, with Groups B, C, and D showing the largest pace increase for this segment (Table 5). Post-hoc tests utilising the Tukey method revealed the average paces for all pairs demonstrated statistically significant differences with $p < 0.0001$ (Table 5).

Table 5: Pairwise comparison of mean differences in change of pace across the different segments of each group. SE=Standard Error, DF=Degree of freedom. Within each group the change of pace is compared between segments. A1-A2 shows mean difference in change of pace from Segment 1 to Segment 2 for Group A. Thereafter, from Segment 2-3, and 3-4. The same principle applies for Groups B-H.

Group & Segment	Estimate	SE	DF	T-ratio	p-value
A1-A2	0.90693	0.0769	101186	11.796	<0.0001
A2-A3	1.67085	0.0769	101186	21.731	<0.0001
A3-A4	-0.87160	0.0769	101186	-11.336	<0.0001
B1-B2	1.59006	0.0374	101186	42.459	<0.0001
B2-B3	1.64592	0.0374	101186	43.950	<0.0001
B3-B4	-1.13333	0.0374	101186	-30.263	<0.0001
C1-C2	1.64811	0.0268	101186	61.461	<0.0001
C2-C3	1.58603	0.0268	101186	59.146	<0.0001
C3-C4	-1.13715	0.0268	101186	-42.406	<0.0001
D1-D2	1.47887	0.0175	101186	84.506	<0.0001
D2-D3	1.20899	0.0175	101186	69.084	<0.0001
D3-D4	-1.13894	0.0175	101186	-65.081	<0.0001
E1-E2	1.38716	0.0161	101186	85.900	<0.0001
E2-E3	1.18532	0.0161	101186	73.401	<0.0001
E3-E4	-1.04735	0.0161	101186	-64.856	<0.0001
F1-F2	1.30925	0.0127	101186	103.262	<0.0001
F2-F3	0.90647	0.0127	101186	71.494	<0.0001
F3-F4	-1.07654	0.0127	101186	-84.908	<0.0001
G1-G2	1.39365	0.0150	101186	93.156	<0.0001
G2-G3	0.85975	0.0150	101186	57.468	<0.0001
G3-G4	-0.88217	0.0150	101186	-58.967	<0.0001
H1-H2	1.52989	0.0144	101186	106.281	<0.0001
H2-H3	0.61262	0.0144	101186	42.628	<0.0001
H3-H4	-0.82929	0.0144	101186	-57.611	<0.0001

3.3.3. Pacing profile per segment between Group A and each of the other groups.

Pairwise comparison results (Table 6) showed Group B had the lowest estimated mean difference of average pace at each segment when compared against the corresponding segments of Group A ($p < 0.0001$). Group H had the highest estimated mean difference when compared to Group A ($p < 0.0001$), as expected due to the way the groups were set up.

Table 6: Pairwise comparisons of mean differences in change of running speed across different segments of each group compared to Group A. SE=Standard Error, DF=Degree of freedom.

Group & Segment	Estimate	SE	DF	T-ratio	p-value
A1-B1	1.68697	0.0605	101186	27.896	<0.0001
A2-B2	2.37003			39.193	<0.0001
A3-B3	2.34517			38.780	<0.0001
A4-B4	2.08343			34.452	<0.0001
A1-C1	3.28266	0.0576	101186	57.012	<0.0001
A2-C2	4.02384			69.884	<0.0001
A3-C3	3.939.2			68.411	<0.0001
A4-C4	3.67347			63.799	<0.0001
A1-D1	4.88547	0.0558	101186	87.620	<0.0001
A2-D2	5.45741			97.878	<0.0001
A3-D3	4.99556			89.594	<0.0001
A4-D4	4.72822			84.800	<0.0001
A1-E1	6.01904	0.0556	101186	108.348	<0.0001
A2-E2	6.49927			116.992	<0.0001
A3-E3	6.01374			108.252	<0.0001
A4-E4	5.83800			105.083	<0.0001
A1-F1	7.06332	0.0551	101186	128.188	<0.0001
A2-F2	7.46564			135.490	<0.0001
A3-F3	6.70126			121.618	<0.0001
A4-F4	6.49632			117.898	<0.0001
A1-G1	7.76994	0.0554	101186	140.286	<0.0001
A2-G2	8.25666			149.074	<0.0001
A3-G3	7.44556			134.429	<0.0001
A4-G4	7.43499			134.238	<0.0001
A1-H1	8.38722	0.0553	101186	151.636	<0.0001
A2-H2	9.01017			162.899	<0.0001
A3-H3	7.95294			143.785	<0.0001
A4-H4	7.99525			144.549	<0.0001

3.3.4. Pairwise comparison of changes in pace for Segments 2,3 and 4 when normalised to Segment 1.

Table 7 displays the average pace for each group at Segments 2,3, and 4, expressed as a percentage (%) normalised to Segment 1 (pace of Segment 1 = 100.00%). As shown in Figure 7 all groups evidently slowed from Segment 1 – 3 before an eventual pace increase in Segment 4. Group A better sustained their pace in Segment 2 and 3 when compared to Segment 1, with

the rest of the field demonstrating progressively larger changes in pace over these segments (Table 4). Similarly, Group A better sustained their pace and demonstrated the smallest estimated mean difference in pace changes between their final Segment 4 (50-56 km) pace and their starting pace in Segment 1 (0-28 km). Group A completed the final segment of the race at a pace <10% of that than their average starting pace in Segment 1 (Table 7). The rest of the field from Group B did not follow in chronological order as they demonstrated varying differences that is Group F displayed the second fastest finishing pace in Segment 4, compared to their respective starting pace, in Segment 1 behind Group A. Whereas, Group C's final segment was the slowest.

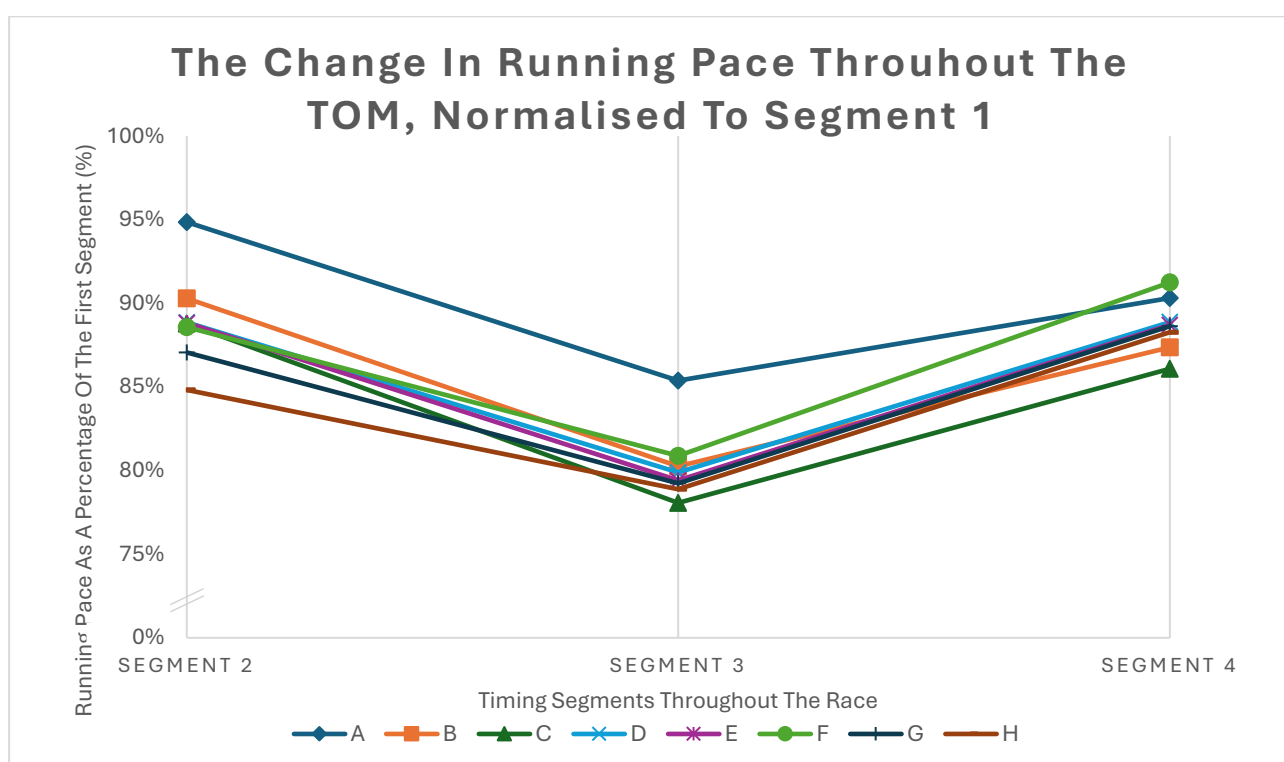


Figure 8: The change of pace of each group (A-H) expressed as a percentage (%) normalised to Segment 1, for Segments 2, 3 and 4.

Table 7: Estimated marginal means of pace per segment expressed as a percentage (%) of pace, normalised to Segment 1 (100.00%) for Groups A-H. SE = Standard Error; DF= Degree of freedom; CL = Confidence Level.

Group & Segment	Estimated marginal mean pace	SE	DF	Lower CL	Upper CL
A1	100.00	0.6163	101258	98.79	101.21
A2	94.85			93.64	96.06
A3	85.39			84.18	86.59
A4	90.35			89.14	91.56
B1	100.00	0.3002	101258	99.41	100.59
B2	90.19			89.60	90.77
B3	80.10			79.51	80.69
B4	87.24			86.65	87.83
C1	100.00	0.2150	101258	99.58	100.42
C2	88.85			88.42	89.27
C3	78.10			77.68	78.52
C4	86.02			85.59	86.44
D1	100.00	0.1403	101258	99.73	100.28
D2	88.82			88.54	89.09
D3	79.64			79.36	79.91
D4	88.53			88.25	88.80
E1	100.00	0.1294	101258	99.75	100.25
E2	88.47			88.22	88.73
E3	78.45			78.19	78.70
E4	87.46			87.21	87.72
F1	100.00	0.1016	101258	99.80	100.20
F2	87.99			87.79	88.19
F3	79.57			79.37	79.77
F4	89.76			89.56	89.96
G1	100.00	0.1199	101258	99.77	100.24
G2	86.18			85.95	86.42
G3	77.55			77.31	77.78
G4	86.53			86.29	86.76
H1	100.00	0.1154	101258	99.77	100.23
H2	83.74			83.51	83.96
H3	77.18			76.95	77.40
H4	86.18			85.95	86.40

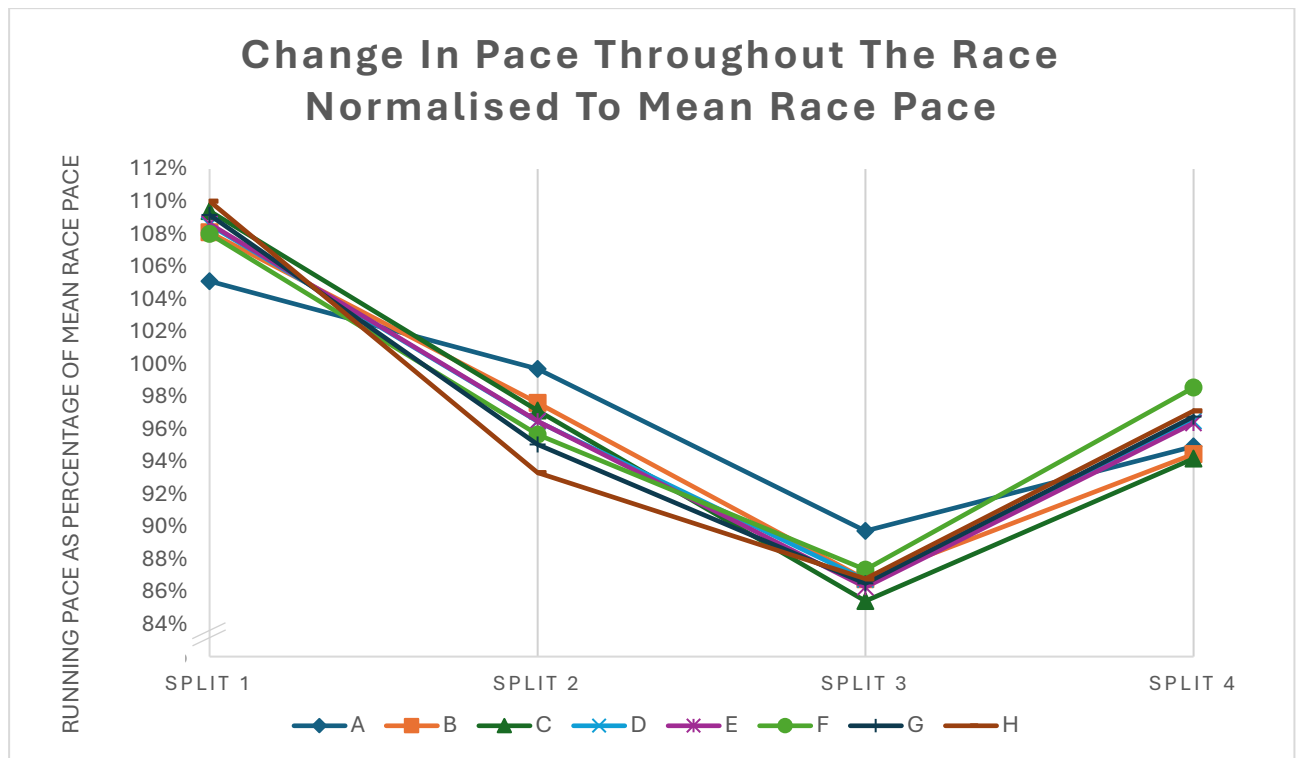


Figure 9: The change of pace of each group (A-H), normalised to the overall mean race pace and expressed as a percentage (%), for Segments 1, 2, 3 and 4.

3.3.5. Pairwise comparison of changes in pace for Segments 1, 2, 3 and 4 when normalised to mean race pace (MRP).

Table 8 depicts average pace normalised to the mean race pace of each group expressed as a percentage (%), for Segments 1, 2, 3, and 4. The slowest finishers, Group H, started the race (Segment 1) the fastest relative to overall race pace, at 111.40% of their overall MRP (CI= 4.99 – 7.47; $p < 0.001$). Contrastingly, the fastest runners of the field, Group A, started their race at 105.17% (CI=3.96 – 6.39; $p < 0.001$) of their MRP. Overall, the slower runners in the field showed a higher starting pace when expressed as a percentage of their MRP (Table 8). Group A demonstrated the least amount of variability throughout the race distance (Figure 9).

Table 8: Estimated marginal means of changes in pace for Segments 1, 2, 3 and 4 expressed as a percentage (%) normalised to overall mean race pace for Groups A-H. SE = Standard Error; DF= Degree of freedom; CL = Confidence Level.

Group & Segment	Estimated marginal mean pace	SE	DF	Lower CL	Upper CL
A1	105.17	0.49098	101186	104.21	106.14
A2	99.67			98.71	100.64
A3	89.63			88.67	90.59
A4	94.85			93.89	95.81
B1	108.38	0.23914	101186	107.91	108.85
B2	97.56			97.09	98.03
B3	86.40			85.93	86.87
B4	94.13			93.66	94.60
C1	109.76	0.17124	101186	109.43	110.10
C2	97.15			96.81	97.48
C3	85.02			84.81	85.35
C4	93.73			93.39	94.06
D1	109.08	0.11175	101186	108.86	109.30
D2	96.44			96.22	96.66
D3	86.11			85.89	86.33
D4	5.87			95.65	96.09
E1	109.54	0.10312	101186	109.34	109.74
E2	96.45			96.25	96.65
E3	85.26			85.06	85.47
E4	95.16			94.96	95.36
F1	109.03	0.08096	101186	108.87	109.19
F2	95.51			95.35	95.67
F3	86.17			86.01	86.33
F4	97.30			97.14	97.46
G1	110.48	0.09553	101186	110.29	110.67
G2	94.85			94.66	95.03
G3	85.21			85.02	85.40
G4	95.09			94.90	95.27
H1	111.40	0.09192	101186	111.22	111.58
H2	92.94			92.76	93.12
H3	85.57			85.39	85.75
H4	95.58			95.40	95.76

3.4. DISCUSSION

This study's main findings demonstrate several key insights:

Firstly, pacing patterns are remarkably similar across all groups of runners (Groups A-H), regardless of their speed. Initially, all runners showed a slowdown from Segment 1-3 (0-50km), followed by a pace increase in the final segment (50km to the finish at 56km), depicting a reverse J-shaped parabolic pattern (Figure 7). Secondly, as expected due to grouping, the fastest finishers (Group A) consistently achieved the highest running speeds across all segments (Figure 7 and Table 4). Lastly, Group A also exhibited the least variability in pace between segments compared to the rest of the field (Table 5). Notably, they started the race more conservatively, maintaining a pace closer to their overall mean race pace in the first half (Segment 1) ($p < 0.001$) compared to the rest of the field (Figure 9).

The results of this study contrast with traditional marathon tactics that historically favoured positive pacing throughout the race. Modern elite marathoners have increasingly adopted negative pacing strategies in their pursuit of faster finishing times (Doherty, Keogh, Smyth, *et al.*, 2020). Recent studies suggest that negative pacing or maintaining a constant pace may be more metabolically economical (Vernillo *et al.*, 2019; Doherty, Keogh, Smyth, *et al.*, 2020; García-Manso *et al.*, 2021; Genitrini *et al.*, 2022). Marathon runners aiming for optimal performance strive to minimise variability in pace, aiming for as even a pacing pattern as possible. While adopting even pacing has been proposed as ideal, complete elimination of variability is challenging, often resulting in either positive or negative pacing patterns (Abbiss and Laursen, 2008; Matta *et al.*, 2020). Elite runners typically exhibit less variation in speed between their faster and slower segments, as observed in the current analysis (Figure 7). Additionally, the findings of this study (Table 5) align with other research indicating that recreational runners often exhibit high variability in pace between their faster and slower segments (Haney and Mercer, 2011)

Positive pacing is well-documented in ultra-marathons, particularly in trail races exceeding 100km, where all runners tend to progressively slow throughout the race regardless of individual performance, whether they are medallists, achieve a personal best, or simply finish the race (Knechtle *et al.*, 2010; Parise and Hoffman, 2011; Tan, Tan and Bosch, 2016). However, in contrast to these established findings, this study of the TOM race indicates that runners adopt a reverse J-shaped pattern, likely due to its shorter nature and course profile. Similar reverse J-shaped patterns observed across all groups in this study (Figure 7) contrast with the pacing patterns seen in shorter events, such as half marathons which often show parabolic U-shaped patterns, and traditional marathons known for positive pacing (Casado *et al.*, 2020). Modern elite marathoners have increasingly adopted negative pacing strategies in

their pursuit of faster finishing times, departing from historical marathon tactics favouring positive pacing (Doherty, Keogh, Smyth, *et al.*, 2020).

Researchers typically describe pacing by comparing running speeds in the first versus second half of a race (Abbiss and Laursen, 2008; Deaner, Addona and Hanley, 2019). Figure 7 illustrates that mean running speeds for all groups were fastest in Segment 1 (which comprises 50% of the race), followed by a progressive decline in pace from Segment 2 to 3, until runners completed 50km (90% of the race). In the final 6km (Segment 4), all groups displayed an increase in pace (Figure 7 and Table 4). Therefore, the initial pace for all groups starts positively, with the first half of the race being run at a higher speed than the second half. Positive pacing, with periods of increased speed in the final 10% of the event, typically results in parabolic-shaped pacing (Abbiss and Laursen, 2008), which can take forms such as U-shaped, J-shaped, or reverse J-shaped (Tan, Tan and Bosch, 2016). Figure 7 notably resembles a reverse J-shaped pacing pattern. The increase in pace during Segment 4, often termed the "end-spurt phenomenon" (Tan, Tan and Bosch, 2016), may not be a true end-spurt due to the downhill nature of the final segment, which alters speed dynamics compared to a flat course.

The gradual decrease in average race pace through Segments 1-3 resembles positive pacing, while the speed increase in the latter stage of the race suggests negative pacing. This interplay results in a parabolic-shaped pacing pattern, specifically a reverse J-shape. However, marathon pacing is influenced not only by physiological factors but also by race characteristics such as course profile and environmental conditions (Oficial-Casado *et al.*, 2020). The relatively flat first half of the TOM course (Figure 1) allows for a faster start compared to the hilly second half (Figure 2), where running speeds naturally decline. Therefore, the course profile significantly impacts pacing patterns, contributing to speed reductions beyond fatigue, particularly due to hills after the initial segment and speed increases due to the downhills after 50km. Hence, pacing patterns are not solely determined by physiological factors.

The course profile of a race affects pacing, typically resulting in positive or reverse J-shaped pacing in ultra-marathons (Matta *et al.*, 2020). In the TOM analysis, all groups displayed similar pacing changes across race segments (Figure 7). All groups slowed from the end of Segment 1 through Segments 2 and 3 (Figure 7). Pairwise comparison data (Table 5) indicates smaller changes in pace during Segments 2 and 3 for non-elite athletes (groups B-H). Non-elite runners often start too fast, evident from the high percentage of mean race pace in Segment 1 (Figure 9), leading to significant subsequent slowdowns in the middle stages of the race. Notably, faster non-elite groups (Groups B and C) exhibited larger pace declines in Segments 2 and 3 compared to slower groups (Groups D-H). Slower runners in Groups D-H may have adopted a slower running or walk-run rhythm by Segments 2 and 3 to mitigate fatigue from

prolonged running and the challenging second half race profile. This explains the smaller pace changes in these segments for the slowest groups (D-H) (Table 5). This finding aligns with studies suggesting non-elite runners often start endurance events too fast, resulting in higher pace variability throughout (Smyth, 2018). Figure 9 further illustrates this trend, with non-elite runners completing Segment 1 of TOM 8-11% faster than their overall mean race pace (Table 8). Additionally, recent studies indicate male participants tend to overestimate their pacing capability and start races too aggressively (Smyth, 2021).

The results indicate that faster finishers managed to maintain their pace better throughout the second half of the race, consistent with the optimal power principle for achieving faster marathon times (Angus, 2014). Observational studies of Olympic and Championship marathons similarly show that medallists exhibit less variability in pacing, favouring even pacing patterns, while slower runners typically display positive pacing (Hanley, 2016; Hettinga, Edwards and Hanley, 2019). Faster finishing times in ultra-marathons are associated with more even pacing profiles across different distances and durations (Parise and Hoffman, 2011; Matta *et al.*, 2020). However, a study of elite male runners at the Berlin marathon found that slower finishers often exhibit positive pacing, while faster finishers tend towards more even pacing (Muñoz-Pérez *et al.*, 2023). Moreover, in ultra-endurance events exceeding 100km, faster finishers maintain their initial race pace longer and exhibit less pace variability, resulting in reverse J-shaped pacing profiles (Lambert *et al.*, 2004; Knechtle *et al.*, 2015; Tan, Tan and Bosch, 2016).

Pacing strategy significantly influences performance outcomes in running (Davies *et al.*, 2016; Renfree, Crivoi do Carmo and Martin, 2016; Díaz, Fernández-Ozcorta and Santos-Concejero, 2018; Konings and Hettinga, 2018; Doherty, Keogh, Davenport, *et al.*, 2020). There exists a clear causal relationship between a runner's pacing strategy and their race performance goals (Smyth, 2018; Muñoz-Pérez *et al.*, 2020). Effective management of energy investment throughout an endurance event is critical for optimising marathon performance (Díaz, Fernández-Ozcorta and Santos-Concejero, 2018). Elite runners in this study began the race (Segment 1) approximately 5% faster than their overall mean race pace, indicating a controlled fast start compared to non-elite runners who started much faster relative to their overall mean race pace (Figure 9 and Table 8). Notably, the slowest groups, such as Groups G and H started the fastest, with paces 10% and 11% faster than their respective mean race paces, respectively. Starting too fast can deplete energy stores prematurely, lead to ineffective pacing, and compromise race performance (Buman *et al.*, 2008; Doherty, Keogh, Smyth, *et al.*, 2020; Smyth, 2021).

Considering the consequences of a fast start, a large-scale analysis of 1.7 million recreational runners across 64 races concluded that recreational runners typically start races more than

5% faster than their mean race pace, often leading to poor race outcomes (Smyth, 2018). This fast start is associated with risk-taking pacing, which can exhaust runners and lead to the proverbial "hitting the wall" (Smyth, 2018). Interestingly, very fast finishes or "end-spurts" may indicate overly conservative pacing earlier in the race, potentially resulting in poorer race outcomes (Smyth, 2018). In contrast, in races exceeding 100km, faster finishing times are associated with a pattern where runners complete the first half faster, followed by a slowing pace (positive pacing), contrasting with shorter races (Lambert *et al.*, 2004; Parise and Hoffman, 2011; Tan, Tan and Bosch, 2016).

In summary, this study's findings contrast with previous research predominantly showing positive pacing in ultra-marathons, as all runners demonstrated a parabolic-shaped pacing pattern (reverse J-shape). This may be attributed to unsustainable efforts in the first half of the TOM race or unrealistic performance goals resulting in runners struggling to maintain a steady pace during the second half of the race. However, the challenging second half of the TOM course likely dictates these pacing patterns.

CHAPTER 4: Conclusion and Recommendation

4.1. CONCLUSION

This study aimed to analyse and compare the pacing patterns of elite and non-elite male runners who completed the TOM from 2007-2019.

The commonly observed pacing pattern among both elite and non-elite runners in this study is a pattern of starting fast, progressively slowing throughout the race, and then increasing pace in the final 10% of the race distance, resulting in a parabolic-shaped pacing profile (Reverse J-shape).

In this study, elite runners (Group A) started with the highest initial speeds (km/h), as designed by the study's parameters. However, the noteworthy finding from the analysis was that these runners began more conservatively than the runners in the other groups, running approximately 5% faster than their MRP in the first segment of the race. In contrast, non-elite runners started less conservatively, running the first segment approximately 8%-11% faster than their MRP. While all runners predictably slowed from the first to the second half of the TOM race, elite runners better maintained their pace through the hilly second half compared to non-elite runners, who slowed more. This resulted in less variation in pace among faster runners, which typically correlates with better performance outcomes (Marino, Lambert and Noakes, 2004; Haney and Mercer, 2011; Angus, 2014; Tan, Tan and Bosch, 2016; Díaz, Fernández-Ozcorta and Santos-Concejero, 2018; Suter *et al.*, 2020). Non-elite runners, starting the race substantially faster relative to their MRP, experienced more pronounced slowing in the second half, followed by an end-spurt, contributing to a more pronounced Reverse J-shaped pattern compared to elite runners who maintained a steadier pace throughout.

These findings suggest that slower runners aiming for an optimal pacing strategy should align their pre-race expectations more closely with their physical abilities and avoid the temptation of starting too fast. Instead, adopting a more realistic initial pace, around 5% faster than their MRP, may help them maintain pace more effectively throughout the race, thereby reducing high pace variability between faster and slower segments. By minimising pace variability allow runners to achieve a more consistent power output profile, mitigating physiological fatigue and optimising their overall pacing strategy.

4.2. LIMITATIONS AND RECOMMENDATIONS

Future research would benefit from implementing uniform 5km timing segments throughout the event. Having segments at 5km intervals could assist researchers in gaining a deeper understanding of the pace variability among TOM participants in a competitive setting. It should be noted; however, that this would rely on the race organisers, as segment times are generated individually for each runner using an electronic timing system. This system utilises a chip worn by each runner to activate the computerised system embedded in timing mats at designated locations.

The TOM route is renowned for its challenging second half. Future studies on pacing could greatly benefit from calculating gradient-adjusted pace over the latter part of the race to better comprehend its impact on changes in pace.

CHAPTER 5: Reference list And Appendix

5.1. Reference list

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5.2. Appendix

5.2.1: Appendix 1: Ethics Approval Letter and Annual Progress Report



Form FHS006: Protocol Amendment

HREC office use only (FWA00001637; IRB00001938)			
☒ Approved	☒ Type of review: Expedited	☐ Full committee	
This serves as notification that all changes and documentation described below are approved.			
Signature HREC Chairperson / Designee		Date	9/6/22
Note: All Major amendments must include a Cover Letter and a local PI Synopsis justifying the changes for the amendment. Please note that incomplete amendment submissions will not be reviewed. Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za with subject line: FHS006 + (HREC Reference number). The latest forms are found on our website. http://www.health.uct.ac.za/fhs/research/humanethics/forms Please also clarify your plan for research-related activities during COVID-19 lockdown.			
Comments from the HREC to the Principal Investigator:			
Note: The approval of this protocol amendment does not grant annual approval. Please complete the FHS016 / FHS017 form for annual approval at least one month before study expiration.			

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	14 July 13, 2022		
HREC REF Number	287/2022		
Protocol Title	A comparison of the pacing profiles adopted by elite versus non-elite male runners in the Comrades Marathon		
Protocol Number (if applicable)			
Principal Investigator	A/Prof Andrew Bosch		
Department / Office Internal Mail Address	HUB, Division of Physiological Sciences		
1.1 Is this a major or a minor amendment? (see FHS006hlp) Major (tick box) Minor (tick box)		x Major	



1.2 Does this protocol receive US Federal funding?	☐ Yes	☒ No
1.3 If the amendment is a major amendment <u>and</u> receives US Federal Funding, does the amendment require full committee approval? Note: Any protocol amendments for Full Committee Review MUST be submitted on the monthly HREC submission dates. (Please email an electronic copy to hrec-enquiries@uct.ac.za)	☐ Yes	☐ No
1.4 Did the initial study require UCT No-Fault Insurance	☐ Yes	☒ No

2. List of Proposed Amendments with Revised Version Numbers and Dates

Please itemise on the page below, all amendments with revised version numbers and dates, which need approval.

This page will be detached, signed and returned to the PI as notification of approval. Please add extra pages if necessary.

The revisions itemized below can be summarized in the following way: The study that was approved by HREC was to analyse past race results of male runners in the Comrades Marathon "Up" run. This amendment request is to include female runners, and to include the "Down" run as well in the analysis, and to include a second ultra-marathon, the Two Oceans Marathon. In all cases, its past race times that will be analysed. No data will be collected. The justification/ rationale for the amendment is that it makes sense to include females as well as males, and also to not do the analysis for "just" the "Up" run, but to include the equally important "Down" run and the other major ultra in the world, the Two Oceans Ultra-marathon.

Below are the amendments to accommodate the above. The amended text is highlighted. These amendments have also been included in the full protocol (included with this Amendment submission); Two such protocols have been submitted; one with the amendments highlighted as below, and one clean copy, without any highlighting.

Original title:

A comparison of the pacing profiles adopted by elite versus non-elite male runners in the Comrades Marathon

New title in amended protocol:

A comparison of the pacing profiles adopted by elite versus non-elite male and female runners in the Comrades and Two Oceans Marathons

In the original protocol, the following is stated as the "Aim":

Aim

This study aims to compare the pacing profiles used by elite male runners versus the rest of the male runners in the Comrades Marathon "up" run.

In the amended protocol, this is amended to:

This study aims to:

1. Compare the pacing profiles used by elite male runners versus the rest of the male runners in the Comrades Marathon "up" run (The original aim)
2. Compare the pacing profiles used by elite female runners versus the rest of the female runners in the



Comrades Marathon "up" run.

3. Compare the pacing profiles used by elite male runners versus the rest of the male runners in the Comrades Marathon "down" run.

4. Compare the pacing profiles used by elite female runners versus the rest of the female runners in the Comrades Marathon "down" run.

5. Compare the pacing profiles used by elite male runners versus the rest of the male runners in the Two Oceans Ultra marathon

6. Compare the pacing profiles used by elite female runners versus the rest of the female runners in the Two Oceans Ultra marathon

In the original protocol, there were 3 objectives. These remain as shown below, with the additional objectives added in yellow highlighting:

Objectives

1. To analyse the race results of the Comrades Marathon "Up" run to identify the pacing profiles adopted by the male elite and recreational runners.
2. To compare the pacing profiles of the top male runners to the rest of the field in the Comrades Marathon up run.
3. To compare the top 10 male runners' starting pace in the Comrades Marathon Up run to their pace in their most recent marathon.
4. To analyse the race results of the Comrades Marathon "Up" run to identify the pacing profiles adopted by the female elite and recreational runners.
5. To compare the pacing profiles of the top female runners to the rest of the field in the Comrades Marathon "Up" run.
6. To compare the top 10 female runners' starting pace in the Comrades Marathon "Up" run to their pace in their most recent marathon.
7. To analyse the race results of the Comrades Marathon "Down" run to identify the pacing profiles adopted by the male elite and recreational runners.
8. To compare the pacing profiles of the top male runners to the rest of the field in the Comrades Marathon "Down" run.
9. To compare the top 10 male runners' starting pace in the Comrades Marathon "Down" run to their pace in their most recent marathon.
10. To analyse the race results of the Comrades Marathon "Down" run to identify the pacing profiles adopted by the female elite and recreational runners.
11. To compare the pacing profiles of the top female runners to the rest of the field in the Comrades Marathon "Down" run.
12. To compare the top 10 female runners' starting pace in the Comrades Marathon "Down" run to their pace in their most recent marathon.
13. To analyse the race results of the Two Oceans Marathon to identify the pacing profiles adopted by the male elite and recreational runners
14. To analyse the race results of the Two Oceans Marathon to identify the pacing profiles adopted by the female elite and recreational runners

Research Question

Is there a difference in pacing profiles used by the elite male and female runners compared to the rest of the male and female runners in the Comrades Marathon in both the "up" and "Down" directions, and the Two



Oceans Ultra Marathon?

Methodology

Study design

The purpose of this study is to analyse the race results the previous 10 years of the Comrades Marathon “up” and “Down” runs and the Two Oceans Ultra Marathon. This study will use a retrospective study design.

Data Collection

This study will make use of publicly accessible data which can be accessed on the Comrades Marathon and Two Oceans web sites.⁽²⁶⁾ The complete set of results (from 2000 – 2019) of the Comrades Marathon “up” and “down” run and Two Oceans will be used for this study. This will provide 10 years of race results and intermediate (split) times, which prevents any significant influence of extreme environmental conditions or minor route changes from influencing the pacing profiles. Each set of results contains the following information on each runner who completed the race each year: The official finishing time, the time at each timing check point and the runners’ overall position.

For data analysis, the eight timing check points within the race (see table 1) will be used. The relative average speed between each segment (one check point to the next) will be calculated individually for each participant.

A second part of this study will be to compare the starting pace of the elite male and female runners in the Comrades and Two Oceans Marathon, to their marathon pace at a time close to their Comrades/ Two Oceans performance. Their marathon pace will be determined from a best marathon time close to the Comrades or Two Oceans data being analysed, available from international race databases.

Participants

Inclusion Criteria

The latest 10 complete Comrades Marathon “up” and “Down” run and Two Oceans race results will be included for analysis. This includes results from the year 2000 to 2019. The entire database of each race will be used in this study, thus including all the male and female runners who finished the race. From these results, the top 10 male runners in each race will be used to establish the pacing strategy of the elite runners relative to their recent best marathon times.

Exclusion Criteria

~~This study will only consider male runners (female results will be analysed in a separate study) as pacing profiles may differ between male and female. Subsequent studies will compare pacing of males and females. Runners’ results will be excluded if there are split times missing or the data is incompletely loaded or if any runners feature in two or more races. When a runner appears in more than one race result, their first “appearance” will be used and others discarded to avoid statistical bias.~~

Confidentiality

The data used in this study (race times and intermediate times) extends over a decade and has been publicly available since the races took place (the race results are available on the Comrades and Two Oceans Marathon websites).



3. Protocol status (tick ✓)

☐	Open to enrolment
☐	No participants have been enrolled
☒	Closed to enrolment (tick ✓)
☒	Research-related activities are ongoing
☐	Research-related activities are complete, long-term follow-up only
☐	Research-related activities are complete, data analysis only

4. Proposed changes will affect: (tick ✓ all the categories that apply)

Protocol	
☒	Study objectives, design (including investigator's brochure, clinical activities, study length)
☐	Study instruments, questionnaires, interview schedules
☐	Sample size
☐	Recruitment methods
☐	Eligibility criteria (inclusion and exclusion criteria)
☐	Drug/device (composition, amount, schedule, route of administration, combination with other drugs/devices, safety information)
☐	Data collection/ analysis
☐	Principal Investigator. (Please attach revised conflict of interest and PI declaration statements. Refer: sections 7 and 8.4 in the New Protocol Application Form FHS013)
☐	Consent form and information sheet
☐	Recruitment materials (e.g. advertisements)
☐	Administrative (e.g. change in sponsor's name, change in contact information)
☒	Other. Please specify: Addition of female runners, addition of Comrades "Down" results, addition of results from Two Oceans marathon

**Note: Amendment changes involving study length, sample size, additional sites and eligibility criteria (i.e. inclusion of minors and /or pregnant woman) need to be declared to the Insurance office. Please liaise via fhs.sponsorship@uct.ac.za regarding the required documentation and information to be submitted to obtain an updated UCT No-fault Insurance Certificate- it should be included herewith*

4.1 In your opinion, will there be any increase in risk, discomfort or inconvenience to participants?	☐ Yes	☐ No NA
If yes, please provide a detailed justification/explanation:		



--

4.2 What follow-up action do you propose for participants who are already enrolled in the study?

☐	Inform current participants as soon as possible
☐	Re-consent current participants with revised consent/assent forms (append)
☐	No action required
☒	Other. Please describe: No participants in study; past race times only

5. Detailed description of the change(s)

Please attach, for each amendment, a summary of all changes which clearly indicates:

- Old wording (e.g. ~~strike through~~ text, CHANGED FROM and CHANGED TO)
- New wording (e.g. *italicized*, **bold**, tracked)
- Detailed rationale/ justification/ explanation for each change

Please refer to point (2) above

6. Ethics Review for Amendment Levy – cost including vat



Amendment Review Costs including VAT

Please tick amount to be billed:

Submission Type	Description	New fee (Vat Incl.)	tick ✓
Research funded solely from UCT departmental/ divisional/group budget	Major/ Minor Amendments	R0,00	✓ ☐
Non-sponsored student research for degree purposes at UCT/Other Universities & Colleges	Major/ Minor Amendments	R0,00	☐
Protocol amendment - Major (FHS006 Form)	Clinical Trial & International Grant Funded Research - Any changes to the protocol that requires Full Committee review	R8 000,00	☐
Protocol amendment - Major (FHS006 Form)	Clinical Trial & International Grant Funded Research - Any change to the protocol that requires Expedited review that does not require Full Committee Review	R5 000,00	☐
Protocol amendment - Minor (FHS006 Form)	Clinical Trial & International Grant Funded Research - Minor amendments, administrative changes that do not affect study design e.g. changes to informed consent form, changes in study staff, etc.	R2 250,00	☐
Protocol amendment - Major (FHS006 Form)	National grant funded research - Any change to the protocol that requires Full Committee review	R7 000,00	☐
Protocol amendment - Major (FHS006 Form)	National grant funded research - Any change to the protocol that requires Expedited review that does not require Full Committee review	R2 500,00	☐
Protocol amendment - Minor (FHS006 Form)	National grant funded research - Minor amendments, administrative changes that do not affect study design e.g. changes to informed consent form, changes in study staff, etc.	R1 000,00	☐

NB: Protocols funded by UCT (e.g. departmental funding / student research) and by certain grant funding organizations (e.g. MRC, NRF, CANSA,) are exempt from these charges.

Please provide details for Invoicing, either complete section 1 or 2 :

1. Invoice billing – Directly to Sponsor

Sponsor's name	
Billing Address of Sponsor:	
Vat Number:	
Contact person:	
Telephone number:	
Email Address:	

2. Internal Journal Billing:

Fund Number:	
Cost Centre Number:	
Account Holder Name:	
Division of Account Holder:	



7. Amendment Submission checklist (tick ✓)

7.1 Please tick that all the documents are attached before submitting to the HREC. NB: Incomplete submissions will not be processed	
☒	Latest FHS006 form completed with all sections completed as per our website
☒	Cover Letter
☒	PI Justification/ Summary for the reasons for the amendment
☒	Protocol - Track changes & Clean Copy (where necessary)
NA ☐	Informed Consent Forms (ICF), if applicable (Any changes made to ICF tracked & clean copy)
NA ☐	Any other additional documentation in support of amendment
NA ☐	Updated no fault insurance certificate (if applicable)

Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za with subject line: FHS006 + (HREC Reference number). The latest forms are found on our website.

8. Signature

My signature certifies that I will maintain the anonymity and/ or confidentiality of information collected in this research. If at any time I want to share or re-use the information for purposes other than those disclosed in the original approval, I will seek further approval from the HREC.			
Signature of PI	Signed by candidate	Date	14/07/2022



Form FHS006: Protocol Amendment

HREC office use only (FWA00001637; IRB00001938)			
☒ Approved	☒ Type of review: Expedited	☐ Full committee	
This serves as notification that all changes and documentation described below are approved.			
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Comments from the HREC to the Principal Investigator:			
Note: The approval of this protocol amendment does not grant annual approval. Please complete the FHS016 / FHS017 form for annual approval at least one month before study expiration.			

Principal Investigator to complete the following:

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Protocol Number (if applicable)			
Principal Investigator	A/Prof Andrew Bosch		
Department / Office Internal Mail Address	HUB, Division of Physiological Sciences		
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1.2 Does this protocol receive US Federal funding?	☐ Yes	☒ No
1.3 If the amendment is a major amendment <u>and</u> receives US Federal Funding, does the amendment require full committee approval? Note: Any protocol amendments for Full Committee Review MUST be submitted on the monthly HREC submission dates. (Please email an electronic copy to hrec-enquiries@uct.ac.za)	☐ Yes	☐ No
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Comrades Marathon "up" run.

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Participants

Inclusion Criteria

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~~This study will only consider male runners (female results will be analysed in a separate study) as pacing profiles may differ between male and female. Subsequent studies will compare pacing of males and females. Runners’ results will be excluded if there are split times missing or the data is incompletely loaded or if any runners feature in two or more races. When a runner appears in more than one race result, their first “appearance” will be used and others discarded to avoid statistical bias.~~

Confidentiality

The data used in this study (race times and intermediate times) extends over a decade and has been publicly available since the races took place (the race results are available on the Comrades and Two Oceans Marathon websites).



3. Protocol status (tick ✓)

☐	Open to enrolment
☐	No participants have been enrolled
☒	Closed to enrolment (tick ✓)
☒	Research-related activities are ongoing
☐	Research-related activities are complete, long-term follow-up only
☐	Research-related activities are complete, data analysis only

4. Proposed changes will affect: (tick ✓ all the categories that apply)

Protocol	
☒	Study objectives, design (including investigator's brochure, clinical activities, study length)
☐	Study instruments, questionnaires, interview schedules
☐	Sample size
☐	Recruitment methods
☐	Eligibility criteria (inclusion and exclusion criteria)
☐	Drug/device (composition, amount, schedule, route of administration, combination with other drugs/devices, safety information)
☐	Data collection/ analysis
☐	Principal Investigator. (Please attach revised conflict of interest and PI declaration statements. Refer: sections 7 and 8.4 in the New Protocol Application Form FHS013)
☐	Consent form and information sheet
☐	Recruitment materials (e.g. advertisements)
☐	Administrative (e.g. change in sponsor's name, change in contact information)
☒	Other. Please specify: Addition of female runners, addition of Comrades "Down" results, addition of results from Two Oceans marathon

**Note: Amendment changes involving study length, sample size, additional sites and eligibility criteria (i.e. inclusion of minors and /or pregnant woman) need to be declared to the Insurance office. Please liaise via fhs.sponsorship@uct.ac.za regarding the required documentation and information to be submitted to obtain an updated UCT No-fault Insurance Certificate- it should be included herewith*

4.1 In your opinion, will there be any increase in risk, discomfort or inconvenience to participants?	☐ Yes	☐ No NA
If yes, please provide a detailed justification/explanation:		



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4.2 What follow-up action do you propose for participants who are already enrolled in the study?

☐	Inform current participants as soon as possible
☐	Re-consent current participants with revised consent/assent forms (append)
☐	No action required
☒	Other. Please describe: No participants in study; past race times only

5. Detailed description of the change(s)

Please attach, for each amendment, a summary of all changes which clearly indicates:

- Old wording (e.g. ~~strike through~~ text, CHANGED FROM and CHANGED TO)
- New wording (e.g. *italicized*, **bold**, tracked)
- Detailed rationale/ justification/ explanation for each change

Please refer to point (2) above

6. Ethics Review for Amendment Levy – cost including vat



Amendment Review Costs including VAT

Please tick amount to be billed:

Submission Type	Description	New fee (Vat Incl.)	tick ✓
Research funded solely from UCT departmental/ divisional/group budget	Major/ Minor Amendments	R0,00	✓ ☐
Non-sponsored student research for degree purposes at UCT/Other Universities & Colleges	Major/ Minor Amendments	R0,00	☐
Protocol amendment - Major (FHS006 Form)	Clinical Trial & International Grant Funded Research - Any changes to the protocol that requires Full Committee review	R8 000,00	☐
Protocol amendment - Major (FHS006 Form)	Clinical Trial & International Grant Funded Research - Any change to the protocol that requires Expedited review that does not require Full Committee Review	R5 000,00	☐
Protocol amendment - Minor (FHS006 Form)	Clinical Trial & International Grant Funded Research - Minor amendments, administrative changes that do not affect study design e.g. changes to informed consent form, changes in study staff, etc.	R2 250,00	☐
Protocol amendment - Major (FHS006 Form)	National grant funded research - Any change to the protocol that requires Full Committee review	R7 000,00	☐
Protocol amendment - Major (FHS006 Form)	National grant funded research - Any change to the protocol that requires Expedited review that does not require Full Committee review	R2 500,00	☐
Protocol amendment - Minor (FHS006 Form)	National grant funded research - Minor amendments, administrative changes that do not affect study design e.g. changes to informed consent form, changes in study staff, etc.	R1 000,00	☐

NB: Protocols funded by UCT (e.g. departmental funding / student research) and by certain grant funding organizations (e.g. MRC, NRF, CANSA,) are exempt from these charges.

Please provide details for Invoicing, either complete section 1 or 2 :

1. Invoice billing – Directly to Sponsor

Sponsor's name	
Billing Address of Sponsor:	
Vat Number:	
Contact person:	
Telephone number:	
Email Address:	

2. Internal Journal Billing:

Fund Number:	
Cost Centre Number:	
Account Holder Name:	
Division of Account Holder:	



7. Amendment Submission checklist (tick ✓)

7.1 Please tick that all the documents are attached before submitting to the HREC. NB: Incomplete submissions will not be processed	
☒	Latest FHS006 form completed with all sections completed as per our website
☒	Cover Letter
☒	PI Justification/ Summary for the reasons for the amendment
☒	Protocol - Track changes & Clean Copy (where necessary)
NA ☐	Informed Consent Forms (ICF), if applicable (Any changes made to ICF tracked & clean copy)
NA ☐	Any other additional documentation in support of amendment
NA ☐	Updated no fault insurance certificate (if applicable)

Please email this form and supporting documents (if applicable) in a combined pdf-file to hrec-enquiries@uct.ac.za with subject line: FHS006 + (HREC Reference number). The latest forms are found on our website.

8. Signature

My signature certifies that I will maintain the anonymity and/ or confidentiality of information collected in this research. If at any time I want to share or re-use the information for purposes other than those disclosed in the original approval, I will seek further approval from the HREC.			
Signature of PI	Signed by candidate	Date	14/07/2022



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			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	☒ 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		HUMAN RESEARCH ETHICS COMMITTEE
Department / Office Internal Mail Address	Supervisor: Prof Andrew Bosch Andrew.bosch@uct.ac.za		29 MAR 2023 HEALTH SCIENCES FACULTY UNIVERSITY OF CAPE TOWN



1.1 Does this protocol receive US Federal funding?	☐ Yes	x No
1.2 If the study receives US Federal Funding, does the annual report require full committee approval?	☐ Yes	☐ No

Note: Any annual approvals for **Full Committee** review **MUST** be submitted on the monthly HREC submission dates.

(Please send electronic copy for full committee review to hrec-submission@uct.ac.za)

If yes in 1.2 please complete section 1.3 below for invoicing purposes

1.3 Ethics Renewal Fee

Please (tick ✓) appropriate box for billing purposes:

<u>Submission Type</u>	<u>Description</u>	<u>New fee (Vat Incl.)</u>	<u>tick ✓</u>
Research funded solely from UCT departmental/divisional/group budget	Annual evaluation of research progress report for re-certification	R0,00	☐
Non-sponsored student research for degree purposes at UCT/Other Universities & Colleges	Annual evaluation of research progress report for re-certification	R0,00	☐
Annual re-certification / Progress report (FHS016 Form)	Clinical Trial & International Grant Funded Research - Annual evaluation of research progress report for re-certification for Full Committee Approval	R7000,00	☐
Annual re-certification / Progress report (FHS016 Form)	Clinical Trial & International Grant Funded Research - Annual evaluation of research progress report for re-certification for Expedited review	R3 710,00	☐
Annual re-certification / Progress report (FHS016 Form)	National grant funded research - Annual evaluation of research progress report for re-certification for Full Committee Approval	R6000,00	☐
Annual re-certification / Progress report (FHS016 Form)	National Grant funded research for Annual evaluation of research progress report for re-certification for Expedited review	R1 500,00	☐

NB: Protocols funded by UCT (e.g. departmental funding / student research) and by certain grant funding organizations (e.g. MRC, NRF, CANSA,) are exempt from these charges.

Please provide details for Invoicing, either complete section 1 or 2 :

1. Invoice billing – Directly to Sponsor

Sponsor's name	
Billing Address of Sponsor:	
Vat Number:	
Contact person	
Telephone number	



Email Address	
2. Internal Journal Billing:	
Fund Number:	
Cost Centre Number:	
Account Holder Name:	
Division of Account Holder:	

2. List of documentation for approval

Research proposal

3. Protocol status (tick ✓)

☐	Open Enrolment
☒	Closed to enrolment (tick ✓)
☐	Research-related activities are ongoing
☐	Research-related activities are complete, long-term follow-up only
☒	Research-related activities are complete, data analysis only
☐	Main study is complete but sub-study research-related activities are ongoing
☐	Study is closed → Please submit a Study Closure Form (FHS010)

4. Enrolment

Number of participants enrolled to date	n/a
Number of participants enrolled, since last HREC Progress report (continuing review)	
Additional number of participants still required	

5. Refusals

Total number of refusals (participants invited to join the study, but refused to take part)	n/a
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6. Cumulative summary of participants

Total number of participants who provided consent	n/a
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Number of participants determined to be ineligible (i.e. after screening)	n/a
Number of participants currently active on the study	n/a
Number of participants completed study (without events leading to withdrawal)	n/a
Number of participants withdrawn at participants' request (i.e. changed their mind)	n/a
Number of participants withdrawn by PI due to toxicity or adverse events	n/a
Number of participants withdrawn by PI for other reasons (e.g. pregnancy, poor compliance)	N/a
Number of participants lost to follow-up. Please comment below on reasons for loss of follow-up.	n/a
Number of participants no longer taking part for reasons not listed above. Please provide reasons below:	n/a

7. Progress of study

Please provide a brief summary of the research to date including the overall progress and the progress since the last annual report as well as any relevant comments/issues you would like to report to the HREC:

The statistical analysis of this study is currently being finalised. Extension is needed to allow for adequate time to complete the dissertation.

There are no issues to report on.

8. Protocol violations and exceptions (tick ✓ all that apply)

☒	No prior violations or exceptions have occurred since the original approval
☐	Prior violations or exceptions have been reported since the last review and have already been acknowledged or approved
☐	Unreported minor violations that have occurred since the last review, as well as significant deviations not yet reported, are attached for review

9. Amendments (tick ✓ all that apply)

☒	No Prior amendments have been made since the original approval
☐	Prior amendments have been reported since the last review and have already been approved



☐	New protocol changes/ amendments are requested as part of this continuing review (See note below)
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Note: If new protocol changes are being requested in this review, please complete an amendment form (FHS006).

Specific changes in the amended protocol and consent/assent forms must be **bolded**, *italicised* or tracked and all changes must include a rationale.

10. Adverse events

10.1 Please provide below or attach a narrative summary of serious adverse events and/ or unanticipated problems since the last progress report. Please indicate changes made to the protocol and informed consent document(s) as a result (if not already reported to the HREC). Please comment on whether causality to any study procedure or intervention could be established.
None to report on.

10.2 Have participants received appropriate treatment/ follow-up/ referral when indicated (e.g. in the case of abnormal or incidental clinical findings, distress or anxiety)?		
☐ Yes	☐ No	☒ Not applicable
If yes, please describe:		

11. Summary of Monitoring and Audit Activities (tick ✓)

11.1 Was this study monitored or audited by an external agency (e.g. SAHPRA, FDA)?		
☐ Yes	☐ No	☒ Not applicable

11.2 Did a Data and Safety Monitoring Board publish a report?		
☐ Yes	☐ No	☒ Not applicable

11.3 If yes, please identify the agency and attach a summary of the findings.					
Agency Name		Report attached	☐ Yes	☐ No	☐ Not applicable
		DSMB report attached	☐ Yes	☐ No	☐ Not applicable

11.4 Has there been any agency, institutional or other inquiry into non-compliance in this study, or any finding of non-compliance concerning a member of the research team?	
☐ Yes	☒ No
If yes, please explain:	



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12. Level of risk (tick ✓)

12.1 In light of your experience of this research, please indicate whether the level of risk to participants has:	
☐	Increased
☐	Decreased
☒	Shown no change
If there has been a change, please explain:	

12.2 Please provide a narrative summary of recent relevant literature that may have a bearing on the level of risk.
None to report on

13. Insurance

Please confirm that valid no fault insurance is still in place? (tick ✓)		
☐ Yes	☐ No	☒ Not Applicable – N/A
If yes, please complete the following:		
Insurer's name:		
Policy no.		*Coverage Period:
<i>For UCT sponsored studies please liaise the Insurance office via fhs.sponsorship@uct.ac.za regarding the required documentation and information required obtain a renewed UCT No-fault Insurance Certificate.</i>		

14. Statement of conflict of interest

Has there been any change in the conflict of interest status of this protocol since the original approval? (tick ✓)	
☐ Yes	☒ No
If yes, please explain and if necessary, attach a revised conflict of interest statement (Section #7 in the New Protocol Application Form FHS013):	



15. Signature

My signature certifies that the above is complete and correct.

Signature of PI	Signed by candidate	Date	29/03/23
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