PERFORMANCE PROFILES AND TRAINING LOADS OF OPTIMIST SAILORS

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Declaration

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This dissertation includes three unpublished publications. The development and writing of the papers were the principle responsibility of myself and, for each of the cases where this is not the case, a declaration is included in the dissertation indicating the nature and extent of the contributions of co-authors.

Date: March 2020

Abstract

Introduction: Despite a growth in competitive sailing, there remains a lack of research available supporting performance analysis and athlete monitoring in sailing. To understand more about the Optimist sailing class, fundamental research into competitive sailing racing and training is needed. Therefore, the overarching aims of this dissertation were to i) determine race performance indicators of high-level Optimist sailing races and ii) to quantify the training loads within different wind intensities of competitive South African Optimist sailors. A secondary aim was to develop an Optimist race performance profile from the IODA Optimist World Championships.

Methods: The dissertation was structured in three parts; part 1 involves a scoping review, which identifies the gaps within the current literature, part 2 establishes race performance indicators and uses these to develop performance profiles of high-level Optimist races, while part 3 is considers the training stress imposed on Optimist sailors during training sessions in different wind intensities. Part 2 followed a retrospective descriptive study design, 28 performance indicators were identified through statistical analyses and sailing coaches input. These were used to build a performance profile of 150 Optimist races from the IODA Optimist World Championships (2014-2018). Performance profiles were developed for the qualifying series and each fleet within the final series. Part 3 was an observational study which monitored 12 high-level competitive South African Optimist sailors during 21 on-water sailing training sessions in varying wind intensities (light, medium and strong). The training loads during the training sessions were monitored using heart rate measures, to determine TRIMP (Training Impulse) and the SHRZ (Summated-Heart-Rate-Zone) score, as well as the session-rating of perceived exertion method. A relationship between these measures and energy expenditure was also determined.

Results: Results in part 2 showed almost perfect relationships between positions at each mark and the final race outcome for all series (*rho*=0.93-0.98, p<0.01). A regression analysis coupled with input from coaches determined time difference from race leader at all marks and the finish, as well as difference in velocity made good from race winner in leg 1 for qualifications and finals as the most important performance indicator predictors. The five variables were inversely associated with less or more time leading to a higher or lower rank for final race outcome. For part 3, session-RPE was higher in strong vs. light wind intensities (p=0.02). The TRIMP scores related to energy expenditure during all wind intensities (*rho*=0.35-0.82). The SHRZ method showed highest total training time in zone 2 (31%; aerobic system) and zone 3 (26%; anaerobic glycolysis system).

Conclusion: Coaches can use the race performance indicators and performance profiles to compare race performances and subsequently give more specific feedback to the sailors. Wind intensity applies an external stimulus to the sailor, thereby contributing to internal load on the sailor. Therefore, using the TRIMP measure for internal load is recommended. This dissertation provides a greater understanding of the race performance indicators and training loads of high-level competitive Optimist sailors. The methods identified and utilised in these investigations may prove useful to sailing coaches when analysing their Optimist sailors' performance during competition and training.

Keywords: *performance indicators, performance profile, training load, sailing, Optimist sailors*

Opsomming

Inleiding: Ten spyte van 'n groei in mededingende seiljagvaart, is daar nogsteeds 'n gebrek aan navorsing beskikbaar om prestasie-analise an atleet-monitering van seiljagvaart te ondersteun. Om meer te verstaan in die Optimist seiljagvaart-klas is fundamentele navorsing oor mededingende seiljagresies en –oefeningsessies nodig. Daarom was die oorkoepelende doelstellings van hierdie proefskrif om i) die prestasie-aanduiders van hoë-vlak Optimist seiljagresies te bepaal en ii) om die oefeningslading van verskillende windintensiteite van mededingende Suid-Afrikaanse Optimist seiljagvaarders te kwantifiseer. 'n Sekondêre doelwit was om 'n Optimist-resies prestasieprofiel van die IODA Optimist Wêreldkampioenskappe te ontwikkel.

Metodes: Die proefskrif is in drie dele gestruktureer; deel 1 behels 'n omvangbepaling, wat die leemtes in die literatuur tans identifiseer, deel 2 stel resiesprestasie-aanduiders vas en gebruik dit om prestasieprofiele van hoë-vlak Optimist resies te ontwikkel, terwyl deel 3 kyk na die oefeningspanning wat opgelê word op Optimist seiljagvaarders tydens oefensessies in verskillende windintensiteite. Deel 2 volg op 'n terugwerkende beskrywende studie ontwerp, en het 28 prestasie-aanduiders geïdentifiseer deur statistiese ontledings en seiljagvaar-afrigters se insette. Hierdie aanduiders was gebruik om 'n prestasieprofiel van 150 Optimist-resies uit die IODA Optimist Wêreldkampioenskappe (2014-2018) op te stel. Prestasieprofiele was ontwikkel vir die kwalifiserende reeks en elke vloot binne die finale reeks. Deel 3 was 'n waarnemingsstudie wat 12 hoë-vlak Suid-Afrikaanse Optimist seiljagvaarders gemonitor het tydens 21 oefensessies op die water in verskillende windintensiteite (lig, medium en sterk). Die oefeningslading gedurende die oefensessies was met behulp van hartslagmetings gemonitor om die TRIMP (‘*Training Impulse*’) en die SHRZ (‘*Summated-Heart-Rate-Zone*’) telling te bepaal, asook die sessie-beoordeling van die waargenome inspanningsmetode. Daar is ook 'n verband tussen hierdie maatstawwe en energie-uitgawes bepaal.

Resultate: Resultate in deel 2 het byna perfekte verwantskappe getoon tussen die posisies by elke punt en die finale uitslag van die resies vir alle reekse (*rho* = 0.93-0.98, p <0.01). 'n Regressie-analise, tesame met die insette van afrigters, het die tydsverskil bepaal tussen r resiesleier by alle punte en die eindpunt, sowel as die verskil in snelheid goed gemaak van die resieswenner in been 1 van die kwalifikasies en eindstryde as die belangrikste voorspellers van prestasie-aanwysers. Die vyf veranderlikes is omgekeerd geassosieer met minder of meer tyd wat lei tot 'n hoër of laer rang vir finale uitslag. Vir deel 3, was sessie RPE hoër in sterk teenoor ligte windintensiteite (p=0.02). Die TRIMP-tellings hou verband met die energie-uitgawes tydens alle windintensiteite (*rho*=0.35-0.82). Die SHRZ-metode getoon het dat die hoogste totale oefentyd in sone 2 (31%; aërobiese stelsel) en sone 3 (26%; anaërobiese glikolise-stelsel) spandeer het.

Afsluiting: Afrigters kan die aanduiders vir resiesprestasies en prestasieprofiele gebruik om resiesprestasies te vergelyk en dan meer spesifieke terugvoering aan die seiljagvaarders te gee. Windintensiteit pas 'n eksterne stimulus op die seiljagvaarder toe, wat daartoe bydra dat interne lading op die seiljagvaarders geplaas word. Daarom word dit aanbeveel dat die TRIMP-maatstaf vir interne lading gebruik word. Hierdie proefskrif bied 'n groter begrip van die prestasie-aanduiders en oefenings ladings van hoë-vlak Optimist seiljagvaarders. Die metodes wat in hierdie ondersoeke geïdentifiseer en gebruik was, mag dalk nuttig wees vir seiljag afrigters wanneer hulle hul Optimist seiljagvaarders se prestasie tydens kompetisie en oefeningsessies ontleed.

Sleutelwoorde: *prestasie-aanduiders, prestasieprofiel, oefenlslading, seiljag, Optimist seiljagvaarders*

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Key Terminology

Athlete monitoring – the methods by which sports scientists investigate the training load (TL; i.e. training stressors, strains and tolerance) an athlete is exposed to during training and competition and in some cases the corresponding response to the training (Cardinale & Varley, 2017).

Capsizing – when a dingy turns upside down because of either too much wind pressure in the sails or not enough counterbalance provided by the sailor.

Dinghy – a lightweight sailing boat, usually sailed by one to three people.

Duration – the total time of the training session, reported in minutes or seconds.

Energy expenditure – the amount of energy which an athlete will use when doing an action or playing sport.

External training load – an objective measure of the work performed, for example, the training volume, session type, distance covered, or power output.

Frequency – how often training occurs (per day, week, month or year).

Global positioning system (GPS) – micro-technology used to objectively measure the positional components of the athlete or boat, through movement tracking.

Gybe – a change in course, where the sailor steers the boat further away from the wind, to the pointer where the sails change sides.

Heart rate – speed of the heartbeat measured by the number of contractions of the heart per minute (bpm).

High-level competitive Optimist sailor – an individual who participates in sailing at elite or national and international level against others as a central component, places a high premium on excellence and achievement, and requires some form of intense systematic training (adapted from the 36th Bethesda conference) (Maron & Zipes, 2005).

Hiking – involves the helm (i.e. the person steering the boat) hooking their feet under a toe strap and leaning out on the windward side of the boat (Chicoy & Encarnación-Martínez, 2015).The aim of the hiking technique is to counterbalance the heeling moment of the boat, created by the force of the wind in the sail, in order to maintain optimal angle and boat speed (Bourgois, Callewaert, Celie, De Clercq & Boone, 2016).

Intensity – the amount of work performed in a unit of time.

Internal training load – a measure of the amount of stress imposed on the athlete either during a single session or over time, for example, heart rate (HR) indices, blood lactate [La] and session rate of perceived exertion (session-RPE).

International Optimist Dinghy Association (IODA) – the international body in charge of the regulation and development of Optimist sailing worldwide.

Junior sailors – sailors aged 15 years or younger.

Knots – unit of wind speed in navigation, 1 knot = 1.852km/hour.

Mark rounding's – turning the boat around a mark placed in the water and changing the angle of the boat to the wind.

Notational analysis – procedure used to identify and analyse critical patterns and events within a sporting performance (Hughes, 2004).

Optimist – a one design sailing dinghy sailed by children 15 years or younger.

Performance – combination of physical, physiological, biomechanical, psychological factors and training techniques which help an individual carry out a sporting activity; and the manner in which participation in sport is measured.

Performance analysis – a method "used to assess quality and/or quantity of performance data in an accurate and consistent manner" (Groom, 2012).

Performance indicators – important action variables that aim to define some or all aspects of sporting performance or outcome (Hughes & Franks, 2004).

Performance profile – analysis of a sport to understand the qualities necessary to be successful within the sport (Butler, 1997); and identifying the strengths and weaknesses of the individuals own race strategies and tactical execution, as well as those used by the opposition.

Regatta – an organised event involving a series of sailing boat races, such as the IODA Optimist World Championships.

Sailing strategies – the relationship between the boat and the environment (Bethwaite, 2011).

Sailing tactics – the relationship between the boat and other competitors in the race (Bethwaite, 2011).

Session rate of perceived exertion (session-RPE) – an individual athletes' subjective perception of the training session intensity.

Successful sailing performance – can be defined as individual performance success (a race result better than the average results for that sailor in the respective regatta) or success in the sport (a podium finish in a regatta).

Tack – a change in course where the sailor steers the boat through the wind, resulting in the sails changing sides.

Training load – the amount of work an athlete performs during a given session, albeit training or competition (volume multiplied by intensity).

Volume – duration of a training session.

List of Abbreviations and Acronyms

% – Percentage
AU – Arbitrary unit
bpm – Beats per minute
CL – Competition load
CI – Confidence interval
GPS – Global positioning system
h – Hour
HR – Heart rate
HR_{max} – Maximum heart rate
HR_{mean} – Average heart rate
HR_{min} – Minimum heart rate
HR_{peak} – Peak heart rate
HR_{rest} – Resting heart rate
iTRIMP – Individual training impulse
kg – Kilogram
KTA – Knowledge to Action framework
kts – Knots
IODA – International Optimist Dinghy Association
m – Metres
m/sec – Metres per second
min – Minutes
n – Sample size
NRF – National Research Fund
OWC – Optimist World Championships
p – Probability
PA – Performance analysis
PI – Performance indicator
PP – Performance profile
rho – Spearman correlation coefficient
RPE – Rating of perceived exertion
sec – Seconds
SAS – South African Sailing
SD – Standard deviation
SEM – Standard error of measurement
SHRZ – Summated-heart-rate-zone
Session-RPE – Session rating of perceived exertion

TL	–	Training load
TRIMP	–	Training impulse
VMG	–	Velocity made good
WI	–	Wind intensity
y	–	Years

Preface

This dissertation follows an article-format based on three separate but equally important parts of the investigation. Consequently, the dissertation does not include a methodology chapter, which is instead discussed in each of the individual research article chapters. The first chapter is a general introduction and overview of the research topic (Chapter 1), followed by a more detailed general narrative literature review (Chapter 2) on the key concepts of the research question, including the problem statement, research aim and objectives. Research article one (Chapter 3) sets out to determine the race performance indicator(s) and performance profiles of Optimist sailors. Whereas research article two (Chapter 4) is a scoping review that considers the background to athlete monitoring in high-level athletes competing in non-motorised surface water sports and provides a more in-depth rationale for the investigation in Chapter 5. Article three (Chapter 5) investigates the acute training load requirements of competitive Optimist sailors. Finally, the dissertation is concluded with an overall conclusion, including study limitations and practical applications, and recommendations for future research (Chapter 6).

The reference list at the end of the dissertation, after Chapter 6, contains the references for all chapters, excluding the individual articles (these are included within the relevant chapter). Chapters 1, 2 and 6 use the American Psychological Association, while Chapters 3, 4 and 5 use the Vancouver referencing style.

CHAPTER 1: INTRODUCTION

Competitive sailing has been around for several years, with the earliest documented race being held in 1851 (Pearson, Hume, Cronin & Slyfield, 2016). Since the introduction of this America's Cup challenge, sailing and consequently sailing racing has developed and evolved. Sailing made its Olympic Games debut when it was contended for the first time in 1900 and has developed into a continually progressing sport based on the advances in yacht design and technology. This has subsequently given an array of people the chance to sail, as they have the opportunity to find a class of boat and specific racing format which suits their age, size and style.

One specific class of boat, the Optimist dinghy, was designed and first sailed in 1947. An Optimist is a one design class for any sailor up to the age of and including the year the sailor turns 15 years old (IODA Basics, 2010). This age group adds another component to consider, in that youth athletes may respond differently to adults. To date, most research investigating sailing has been done on adult sailors. Subsequent to 1947, Optimist sailing has grown more and more popular. It is estimated that between 130 000 and 150 000 under 16-year-old children from 100 to 120 countries sail and/or race in this dinghy (Palomino-Martín, Quintana-Santana, Quiroga-Escudero, & González-Muñoz, 2017; Lopez, Bourgois, Tam, Bruseghini, & Capelli, 2016; www.optiqld.org.au). In 1962, fifteen years after the first Optimist dinghy was built, four countries were represented and competed in the first international Optimist regatta. This regatta has since been renamed the International Optimist Dinghy Association (IODA) Optimist World Championships (OWC) and has successively been held every year.

The goal of any high-level competitive athlete is to improve performance. For the purpose of this dissertation, performance is defined as a quantifiable measure of a sailor's skill during an event, where the overall race or regatta result is the determining factor. Performance indicators (PI(s)) or action variables relating to performance are a means to determine an improvement in performance during the competition (Hughes & Bartlett, 2002). Additionally, race PIs are important to determine because they can provide objective information relating to the outcome of strategic and tactical decisions made throughout the race. With the development of PIs, these action variables can be used to create performance profiles (PP(s)), which have the potential to describe the pattern of performance of a team or individual athlete (O'Donoghue, Mayes, Edwards, & Garland, 2008; Hughes & Bartlett, 2002). Due to the dynamic nature of the sport, sailing races are inherently difficult to observe, and it is nearly impossible for coaches to provide feedback on all parts of a race. Thus, if a sailing race PP exists, it can lead to a better understanding of the within race strategies implemented, thus helping coaches to provide objective feedback to the sailor. However, no race PP for high-level Optimist sailing has been reported in the current published literature thus far.

While performing optimally is the ultimate aim of most athletes, in order to improve skills and knowledge within a sport, all athletes need to undergo training. Sailing is considered an open, dynamic sport type, where decisions and subsequent actions are determined by environmental factors, athlete knowledge and perceptions and the task at hand (Araújo, Davids, Diniz, Rocha, Santos, Dias & Fernandes, 2015) and the quality of opponents (O'Donoghue & Cullinane, 2011). Optimist sailing training programs largely depend on the coach, who may or may not consider the use of sport science principles while developing their training program. Furthermore, few Optimist training programs seem to consider athlete monitoring tools and techniques specifically relating to the training loads (TL(s)) on the athlete. Monitoring training and competition load through a scientific approach are becoming increasingly valuable in modern-day sporting environments (Buchheit, 2014). Athlete monitoring programs are critical for coaches, sports scientists and athletes to determine whether the athlete is adapting to the prescribed training and ultimately improving performance (Kellmann, Bertollo, Bosquet, Brink, Coutts, Duffield, Eriacher, Halson, Hecksteden, Heidari, Kallus, Meeusen, Mujika, Robaza, Skorsji, Venter, & Beckmann, 2018; Torres-Ronda, Ric, Llabres-Torres, de las Heras, & Schelling I del Alcazar, 2016). Furthermore, training programs should be monitored using both external and internal load measures to determine the overall physical and physiological stress or load on the athletes during each session; this ensures the training can be designed or altered for individual athletes (Akubat, Patel, Barrett & Abt, 2012; Borresen & Lambert, 2009).

For apparent reasons, the majority of research on sailing has focussed on the physiological, biomechanical and perceptual aspect of the sport; specific investigations include the movements of the sailors on the boat, decision making at critical points in a race, physical requirements and the sailors' energy consumption while in the hiking position (Bourgois, Callewaert, Celie, De Clercq & Boone, 2016; Araújo et al., 2015; Bojsen-Møller, Larsson & Aagaard, 2015). In addition, some research has been focused on youth sailors such as those competing in the Optimist class (Araújo et al., 2015; Callewaert, Boone, Celie, De Clercq & Bourgois, 2015; Lopez, Bourgois, Tam, Bruseghini, & Capelli, 2016; Callewaert, Boone, Celie, De Clercq & Bourgois, 2014). Previous research on Optimist sailing has explicitly shown that in order to see an improvement in performance, sailors should aim to develop their strength- and speed-oriented coordination (Callewaert et al., 2015). Furthermore, research has recognized that these physical and physiological demands in sailing differ depending on the environmental conditions at the time of performance in the sport (such as wind intensity)

(Manzanares, Menayo, Segado, Salmero´n, & Cano, 2015). Sailing is made challenging since the context within which the sport takes place is inherently uncertain and unstable (Manzanares, Segado & Menayo, 2016), where the participants are continually facing unpredictable variables, such as the environmental conditions and actions of the other boats (opponents) (Araújo, Davids, & Serpa, 2005). Despite the developing knowledge on the physiological and physical aspect of sailing, it is surprising how the TLs and PIs related to sailing performance have not yet been investigated. Therefore, further research that explores the specific training demands (physical requirements) and race PIs relating to Optimist sailing performance is required.

While previous research has highlighted the importance of physiological variables in sailing performance, specifically relating to the “hiking” position, it is surprising that no studies have explored more than one aspect of the sport at a time, such as an entire training session or race. As a result, it seems that coaches and sailors could benefit from an investigation of the overall race PIs as well as the training stress during various training sessions. To understand more about Optimist sailing as a sport, particularly the TLs and possible PIs that sailors are confronted with, more research into Optimist sailing specific training and subsequently, competitive racing is needed. This will contribute towards a race performance profile, which may aid coaches and sports scientist in performance analyses and setting training targets towards measurable performance goals.

In most training environments, the coach, sport scientist, parents and mentors play an essential role in the development of the athlete, particularly in junior athletes such as Optimist sailors. Consequently, monitoring an athlete is an important role of a coach or trainer to best prepare their athlete for the environment the athlete will be exposed to during the competition. Thus, information about the TLs of Optimist sailors is important in helping the coaches and support persons to understand the nature of training the athlete needs to be undertaking to be racing competitively in all environmental conditions. Appropriate load monitoring can help identify whether an athlete is adapting to a training program and subsequently coping with the training demands (Borrensen & Lambert, 2009). Numerous potential measures have been researched and are available to gain an understanding of the TLs of athletes (Borrensen & Lambert, 2009; Foster, Hector, Welsh, Schrager, Green, & Snyder, 1995; Banister, Calvert, Savage, & Bach, 1975), to the researcher’s knowledge, none have been applied to Optimist sailing.

If PIs and TLs of Optimist sailors can be determined and quantified, a more scientific approach can be taken to both the design and monitoring of their respective training programs.

Therefore, this dissertation endeavoured to determine the performance consistency during high-level Optimist sailing regattas, as well as to describe race PIs and develop a performance profile for high-level Optimist sailors within these regattas. We also set out to quantify the acute TLs of high-level competitive Optimist sailors during various wind intensities.

CHAPTER 2: GENERAL LITERATURE REVIEW

2.1 Introduction

This narrative literature review outlines the latest developments in the field of Optimist sailing and performance analysis, specifically athlete monitoring, training loads (TL(s)) and performance indicators (PI(s)). The review is structured to achieve four main objectives; firstly, it provides an overview of sailing performance (i.e. during training and racing) within current scientific literature and considers the level of competitive performance of South African Optimist sailors within the sport. Secondly, it considers the existing literature on performance analysis, specifically performance indicators ((PI)s) performance profiles ((PP)s). The review moves on to a discussion of athlete monitoring, as well as the training loads ((TL)s) currently used in sports. Following this, a number of gaps in the current literature are discussed. The chapter concludes by outlining the problem statement, aims and research questions to be addressed in this dissertation specifically.

To better support talented South African sailors, it is important to improve our understanding of sailing performance and the best method to optimize sailing training and racing within the South African context. In 2009, South African Sailing (SAS), with input from sources including Prof. Istvan Balyi (an expert in Long-term Athlete Development (LTPD) and periodization), sport scientists, sailors, sailing class representatives, sailing coaches and the South African Sports Commission and Olympic Committee (SASCOC) developed a LTPD strategy for sailing in South Africa. An emphasis of the strategy included the starting of knowledge transfer at a young age and helping ensure young sailors remain in the sport. The strategy mentioned many challenges sailing in South Africa has to overcome, such as: lack of finance (for transport, training, support, information distribution), only one or two elite level coaches within the country, insufficient government funding and support, lack of new equipment within the clubs, a decline in membership numbers, poor demographics within the country, little to no use of sport science support for the development of an athlete, lack of international competitive opportunity, and insufficient links between clubs and schools (although this is changing, albeit very slowly). As a result, the primary purpose of this dissertation is to explore and enhance the existing knowledge on athlete monitoring and competitive performance in high-level competitive Optimist sailing. To achieve this the articles within the dissertation are based within the Knowledge to Action (KTA) framework. The KTA framework explains the need to translate research into practice for better performance, as it provides processes for creating and applying knowledge within a real-world setting (Graham, Logan, Harrison, Straus, Tetroe, Caswell, & Robinson, 2006). Two main concepts are described, i) knowledge creation involves the process of synthesizing or tailoring the existing knowledge for individuals who may use it (such as sport scientists and coaches), while ii) the action cycle shows the process of how the knowledge can be applied in real-world environments. This dissertation is framed within the knowledge creation concept in that its primary objective is to present first-generation knowledge in a clear and user-friendly manner (Graham et al., 2006).

To date, sailing in South Africa is still trying to manage many of the challenges identified in the LTPD strategy. Thus, one of the motivations behind this dissertation is to determine what and how junior South African Optimist sailors are doing during training and competition in order share with coaches the need for athlete development and a structured, goal orientated training program.

2.2 Sailing and Sport Science

"*The field we [sailors] play on moves, sometimes imperceptible, often unpredictably, and occasionally violently, under the influence of the tide, current and wind*" Dave Hudson, lifelong sailor (2011).

Sport science is a multi-disciplinary field concerned with maximising competitive sports performance through the application of scientific measures and principles (Haff, 2010; Stone, Sands, & Stone, 2004).

Sailing as a sport is universally popular today due to both cruising and racing options with which to enjoy the activity. Sailing involves the control of a boat as it moves through water; where the movement is initiated and maintained by the forces of the wind acting on the sail (i.e. via the principle of Bernoulli). A boat can be sailed in many directions compared to the wind, such as close-hauled or 'upwind', 'reaching' or 'running' (Figure 2.1). However, one cannot sail a boat directly into the wind (referred to as the 'no-go zone'); thus, sailors use a zigzag pattern to progress to a mark upwind of them, this is termed "beating". With this in mind, and for the purpose of this dissertation, sailing is defined as a non-motorised surface water sport.

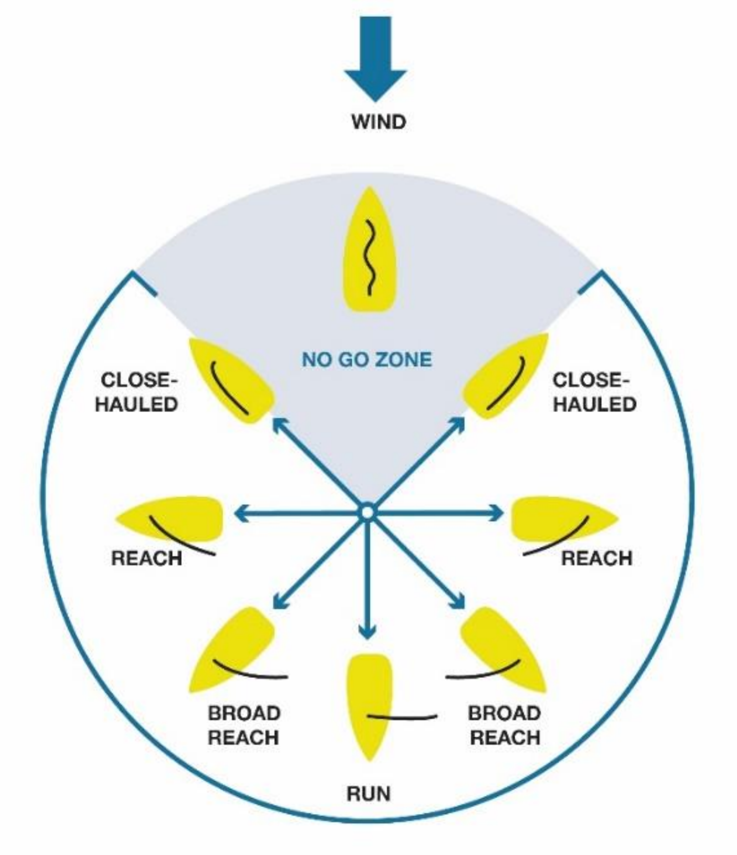


Figure 2.1. Schematic of the sailing angles in relation to the wind direction (Illustrated by Sarah Ferreria © (2019)).

World Sailing© recognises four different formats of sailing racing (specifically ocean racing, course racing, match racing and team racing), each with a fundamental objective to cross the finish line ahead of the competitors. Part of the appeal of sailing is the notion that the principles of the sport are universal; in that they can be applied from the smallest of boats such as the Optimist dinghy to a 75-foot catamaran racing in the prestigious America's Cup. Furthermore, sailing is a sport unlike many other; it is dynamic and unpredictable and as a result, there are many variables that cannot be controlled such as the wind, tide, and the other competitors on the racecourse (Ballegaard, Petersen, Harboe,, & Faber, 2016; Manzanares, Menayo, Segado, Salmero´n, & Cano, 2015; Araújo, Davids, & Serpa, 2005), see Figure 2.2 for more examples. These variables may have a significant influence on the boat and overall race outcome. This dynamic and uncertain aspect of the sport further adds to the appeal of sailing in that the context of individual races are never the same, which in turn challenges the fundamental tactics, skills, as well as the problem solving and decision-making processes of the sailors.

Figure 2.2. Overview of the controllable and uncontrollable elements of dinghy sailing racing.

The International Optimist Dinghy Association (IODA) was founded in 1965, with seven immediate country members. Six countries from Europe (Austria, Denmark, Finland, Great Britain (GB), Norway, Sweden) and one from North America (United States of America (USA)) signed up. As a result from early competition in Optimist World (first held in 1962), North American (created in 1976) and European (created in 1983) Championships some countries, such as USA and GB, have a developed training pathway by which the children can progress to learn and improve sailing skills. In general, we find the highest numbers of youth sailors either learning to sail or currently competing in these countries. This may be because sailing in these countries is widely practiced, have a well-developed training structure and have achieved more success on the international stage, such as the Olympic Games. In contrast, the IODA African Championships was only formally established in 2001. During the most recent IODA African Championships (2019), only 42 sailors participated from eight countries compared to 293 sailors from 49 countries at the IODA European Championships (2019). Gulbin, Weissensteiner, Oldenziel, and Gagné (2013) hypothesised that sports which have high participation numbers are more likely to have well-developed and functioning federations, clubs, infrastructure, coaching development opportunities, funding and competition depth. With this in mind, the researchers further argue that these sports are better able to provide further developmental opportunities for athletes and coaches compared to the sports who suffer from low membership numbers, support (like funding) and cultural significance (Gulbin et al., 2013). This applies to countries, such as South Africa, and specifically with respect to sailing as a professional, performance sport. Sailing in South Africa is rarely considered a conventional school sport (in contrast for example to rugby, hockey, netball, etc.) and thus most of the children who participate in sailing do so privately and are generally only able to sail on weekends or school holidays. As a result, very limited formal sailing and training take place in South Africa during the weekdays.

An initial study in 1997 considered the application of sport science to sailing in New Zealand and the knowledge sailors had with regards to the use of sport science, in the areas of nutrition, psychology and physical conditioning, in their training and subsequent effect on race performance (Mackie & Legg, 1997a). They reported the extent of the knowledge to be modest to good, with some sailors lacking in a few areas. As a result of the findings of this study, Yachting New Zealand adopted a sport science support program for the Olympic class dinghy sailors. In 2000, a follow up article was published (Legg & Mackie, 2000). The researchers showed results of the changes in knowledge and use of sport science one year after the implementation of the support program. The article concluded that the sailors improved their uses of sport science, in the three areas, between 1995 and 1997. Furthermore, and possibly most importantly, the sailors reported this knowledge as a contributing factor in performance improvements. This links to the KTA framework mentioned earlier in that the researchers initially determined and clarified the current level of knowledge the sailors had (knowledge creation) and used this to implement a support program (action cycle) which ultimately helped the athlete’s performance.

Although sailing has been popular in terms of participation and representation in high-level competitions (sailing has appeared at the Olympic Games since 1908); limited research compared to team sports (such as soccer and rugby) has been published on the training modalities and specifics of the sport and athletes. Where, high-level athletes can be defined as *individuals who participates in an organized team or individual sport that requires regular competition (at elite or national and international level) against others as a central component,* *places a high premium on excellence and achievement, and requires some form of intense systematic training* (adapted from the 36th Bethesda conference) (Maron & Zipes, 2005). Research in sailing is growing as more areas within the sport are being considered; specifically, researchers have investigated the effects of decision-making (Araújo et al., 2005), age, experience and anthropometrics (Palomino-Martín, Quintana-Santana, Quiroga-Escudero & González-Muñoz, 2017), injuries (Kostański, Frąckowiak, & Pospieszna, 2019), hydration and nutrition (Slater & Tan, 2007; Tan & Sunarja, 2007), fitness (Santos, Dias, Couceiro, Mendes, & Santos, 2016) and training (Bøymo-Having, Grävare, & Grävare Silbernagel, 2013) on the overall performance of sailors. In 2012, Manzanares, Segado, and Menayo reviewed all literature, focusing on sailing performance, published in scientific journals between 1950 and 2011. The researchers found that 54% of the articles analysed referred to physical characteristics, followed by 22% on technique and decision-making at 14%. The last two categories, strategy (5%) and psychology (3%) were least investigated during the 61year period, possibly due to the difficulty in assessing these skills and the lack of standardised protocols. Since this review more research has investigated decision-making (Araújo et al., 2015; Manzanares et al., 2015), performance (Ballegaard et al., 2016), physical requirements (Bourgois et al., 2016; Bojsen-Møller et al., 2015), physiological responses (Lopez et al., 2016), training habits (Bøymo-Having et al., 2013), performance indicators (Callewaert et al., 2015) and anthropometric variables (Palomino-Martin et al., 2017) in sailors.

2.2.1 Physical and Physiological Demands of Dinghy Sailing

Sailing requires athletes to be in top physical condition and to possess well-learned motor skills due to the intermittent, dynamic nature of the sport. From a physiological point of view Felici, Rodio, Madaffari, Ercolani, and Marchetti (1999) described dinghy sailing as a sport characterised by a relatively low energy requirement but with a high cardiovascular demand.

The specific techniques and demands of dinghy sailing vary from boat to boat, coupled with this we see a range of different physical demands – hiking, trapezing and sail pumping. Prior to 1994, single handed sailing was considered relatively static; where the main physiological task was thought to be the isometric contractions in the lower body and abdominal muscles during the hiking position. Hiking has been described as a bilateral and multi-joint movement which generates fatigue, or quasi-isometric stress, in the anterior leg muscles that cross the knee and hip joint (Spurway, 2007; Sekulic, Medved, Rausavljevi, & Medved, 2006; Maïsetti, Boyas, & Guével, 2006; Vogiatzis, Spurway, Wilson, & Boreham, 1995). Further research on sailing has challenged this view by suggesting that sailing provides greater physiological demands than initially thought (Cunningham, 2004), with an increase in the importance of muscular strength, muscle endurance, and aerobic and anaerobic capacity (Bojsen-Møller et al., 2015). The different roles played by the helm and crew in the various single and double handed sailing classes, require different physiological demands and thus, training and program design need to be centred around the individual sailors and their role on the boat (Bojsen-Møller, Larsson, Magnusson, & Aagaard, 2007). Furthermore, it is important to note that the roles of the helm and crew change during different legs of the course, i.e. upwind and downwind (Draper & Hodgson, 2008). Table 2.1 summarises the predominant physical demands of various sailing class and the roles within these.

Table 2.1. Predominant physical demands of various sailing classes.

Sailing Class	Category	Type	Predominant Physical Demand
Optimist (dinghy)	Mixed	Single handed	Hiking
Laser Standard / Laser Radial (dinghy)	Male and Female	Single handed	Hiking
Finn (dinghy)	Male	Single handed	Hiking
470 / 420 (dinghy)	Male and Female	Double handed	Helm: hiking Crew: trapezing and body pumping (windspeed over 8 knots)
49er / 49erFX (dinghy)	Male and Female	Double handed	Helm: trapezing Crew: trapezing
RS:X (windsurfer)	Male and Female	Single handed	Sail pumping
Nacra17 (multihull)	Mixed team	Double handed	Helm: trapezing Crew: trapezing

Laboratory Performance Studies in Sailing

Laboratory studies on the physiological, biomechanical and physical demands of sailors to evaluate their sport-specific performance is rather difficult. Nonetheless, some researchers have been able to simulate or conduct on-water studies of two of the most common positions dinghy sailors find themselves in when sailing; specifically, the hiking and trapezing positions.

Bojsen-Møller and colleagues (2007) developed a classification system for sailors competing in Olympic class dinghies. This classification system helps to simplify athlete monitoring based on physical requirements, facilitates comparisons between different types of sailors and has enabled sailor-specific training recommendations (Callewaert et al., 2014; Bojsen-Møller et al., 2007). The researchers classify sailors into: (1) “side-deck hikers”, which include most helmsmen and single-handed dinghy sailors; (2) “supported hikers” which are usually sailors on keelboats and (3) trapeze sailors, where the sailor stands on the gunwale and is supported by a wire from the mast. The trapezing technique involves the crew, and helm in some dinghies, suspending their body over the side of the boat by means of a harness worn by the sailor clipped to wire from a point high on the mast. This technique is not necessary for Optimist sailors and is therefore not discussed further. Side-deck hikers are further classified as either 'dynamic hikers' or static hikers' based on the boat characteristics and the way the sailor's control or handle the boat. Based on this classification, Optimist sailors fall into the "side-deck hikers"; whereby hiking involves the helm (i.e. the person steering the boat) hooking their feet under a toe strap and leaning out on the windward side of the boat (Chicoy & Encarnación-Martínez, 2015). In addition to this action, the sailor is constantly trimming the sails and boat to the wind and waves to maintain boat control and speed. During upwind sailing, the helm uses the hiking technique to counterbalance the heeling moment of the boat, created by the force of the wind in the sail, to maintain optimal angle and boat speed (Bourgois et al., 2016; Vogiatzis, Andrianopoulos, Louvaris, Cherouveim, Spetsioti, Vasilopoulou, & Athanasopoulos, 2011; Spurway, 2007; Tan, Aziz, Spurway, To, Mackie, Xie, Wong, Fuss, Teh, 2006).

Research on the physiology of sailing has focused mostly on the hiking technique (Cunningham & Hale, 2007; Mackie et al., 1999; Vogiatzia et al*.*, 1996; Blackburn, 1994; Felici & Marchetti, 1993). The reason for this attention on the hiking technique is that it is generally considered to involve the most effort from the sailors during the race; furthermore, the sailor needs to increase the hiking torque as and when the wind speed increases (Felici et al., 1999). It is important to note that the hiking position in a dinghy is considered a quasi-isometric contraction, therefore the physiological responses when compared to dynamic exercise types are different and must be considered. A study by Iellamo and colleagues (1997) examined the effects of isometric, isokinetic and isotonic submaximal exercise on HR and blood pressure. While all three exercise types produced significant increases in HR, the researchers found that the HR response to isometric exercise was significantly less (up to 50%) ($P < 0.05$) when compared to isokinetic and isotonic exercise at all times (Iellamo, Legramante, Raimondi, Castrucci, Damiani, Foti, Peruzzi & Caruso, 1997). The study found similar results in the response to oxygen uptake (VO_2) during an isometric contraction. Where the VO_2 increased as expected, however this was significantly less ($P < 0.05$) than the other two muscle contraction types. In addition to different cardiovascular and respiratory responses, a dynamic muscle contraction uses more metabolic energy when compared to static or isometric contraction types (Enoke, 2002).

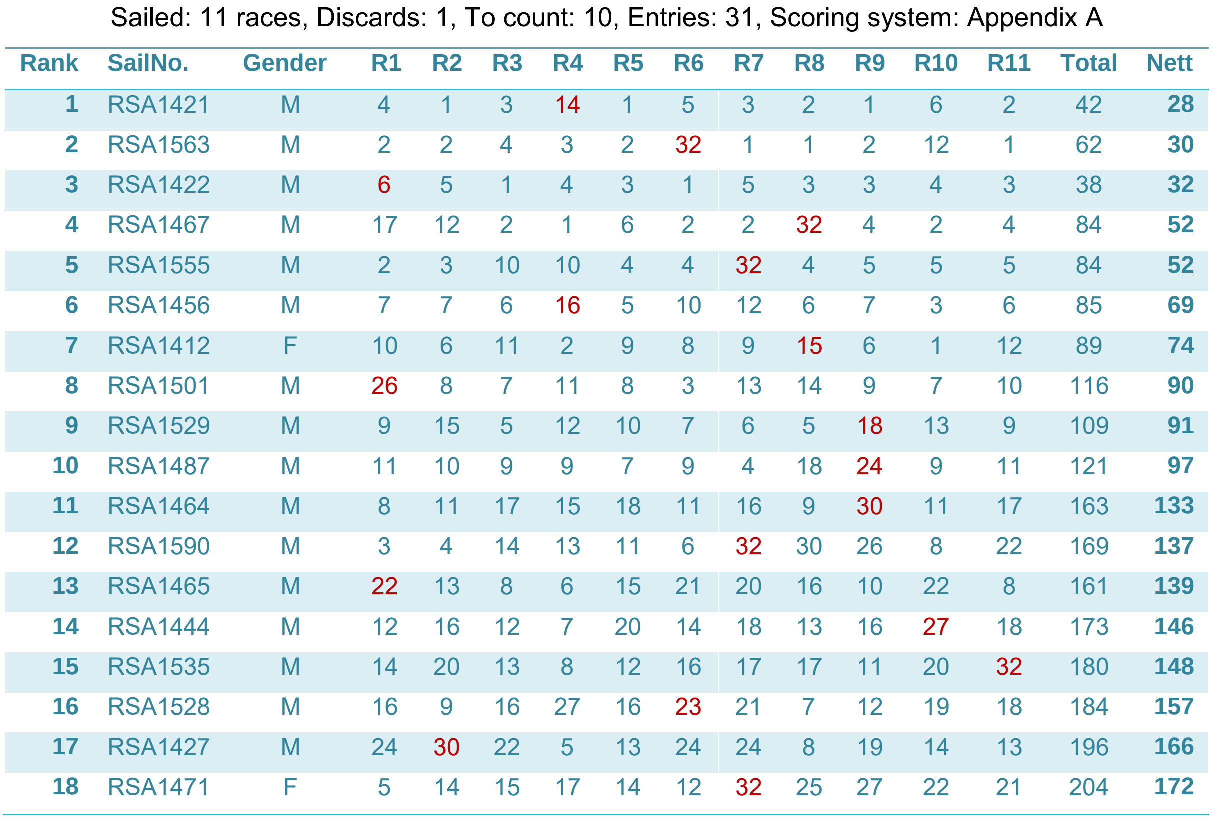
In 1996, researchers showed that the effort of hiking involves an isometric stress sustained at between 30-40% of the quadriceps maximal voluntary contraction and requires 40-50% of the whole body's oxygen uptake (Vogiatzis, Spurway, Jennett, Wilson, & Sinclair, 1996). Furthermore, Vogiatzis and colleagues (2008) indicated that the hiking position results in a decrease in oxygen availability to the quadriceps muscles during repetitive efforts (Vogiatzis, Tzineris, Athanasopoulos, Georgiadou, & Geladas, 2008). Research in 2007 and 2004 confirmed this, by suggesting the demands on the athlete involve isometric muscle contractions coupled with an oxygen consumption rate between 65 and 70% of their maximum aerobic capacity (VO_2max) (Castagna & Brisswalter, 2007; Cunningham, 2004). A higher level of sailing performance is determined by a lower rate of muscle fatigue during the hiking position; this lower rate of fatigue is in turn related to higher maximal isometric quadriceps strength (Bourgois et al., 2016). Based on these findings, the researchers suggested that resistance training plays an important role for sailing performance. In 2006, researchers conducted electromyography (EMG) tests on sailors while in the hiking position (Tan et al., 2006). The results showed that the quadricep muscle region is the most loaded during upwind sailing when hiking. The second highest load was found in the abdominal region. During a race, muscle contraction differs depending on the respective leg of the course, i.e. upwind or downwind and the respective weather conditions. For example, hiking only takes place upwind and more wind will generally require more muscle contraction.

The results of further studies have indicated the importance of a sailor's aerobic capacity for performance, which in turn has resulted in a change in emphasis for dinghy sailing training programs. The helm sailing a Laser, 420 or 470 class boat falls into the dynamic hiker's classification and are required to be very active on the boat; this in turn increases the demand on the aerobic capacity (Bojsen-Møller et al., 2007). Furthermore, training programs need to continue to emphasise the development of isometric endurance in the specific muscle groups (for example quadriceps and abdominals for hikers) (Shepard, 1997).

In summary, aerobic and anaerobic capabilities both seem to be important parameters in competitive sailing. However, one must not forget the importance of perceptual skills and abilities, psychological, personality, decision-making and motivation (Araújo et al., 2005) and technical factors when considering overall performance.

2.2.2 Sailing Racing and Competitive Performance

A sailing competition (or regatta) consists of a series of races over several days. Sailing performance is primarily judged on finishing positions in individual races and the corresponding overall score for a regatta. Additionally, the race is started using a mass start format, i.e. multiple sailors position themselves across the start line to begin the race at the final sound signal. Thus, it is classified as a 'position sport' where efficiency is measured as the ability to go as fast as possible on a predetermine course (Palao & Morante, 2013). Scoring in sailing is based on the finishing positions of the race, where a first place is scored 1 point, second place 2 points and so forth. Therefore, a lower score indicates better performance in the race. Final overall results are the sum of the points (including discretional penalties), less the worst score if more than five races have taken place (IODA, 2013); where the goal is to achieve the lowest number of points in total, see Figure 2.3 for an example of the Appendix A scoring system.



Sailed: 11 races, Discards: 1, To count: 10, Entries: 31, Scoring system: Appendix A

Rank	SailNo.	Gender	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	Total	Nett
1	RSA1421	M	4	1	3	14	1	5	3	2	1	6	2	42	**28**
2	RSA1563	M	2	2	4	3	2	32	1	1	2	12	1	62	**30**
3	RSA1422	M	6	5	1	4	3	1	5	3	3	4	3	38	**32**
4	RSA1467	M	17	12	2	1	6	2	2	32	4	2	4	84	**52**
5	RSA1555	M	2	3	10	10	4	4	32	4	5	5	5	84	**52**
6	RSA1456	M	7	7	6	16	5	10	12	6	7	3	6	85	**69**
7	RSA1412	F	10	6	11	2	9	8	9	15	6	1	12	89	**74**
8	RSA1501	M	26	8	7	11	8	3	13	14	9	7	10	116	**90**
9	RSA1529	M	9	15	5	12	10	7	6	5	18	13	9	109	**91**
10	RSA1487	M	11	10	9	9	7	9	4	18	24	9	11	121	**97**
11	RSA1464	M	8	11	17	15	18	11	16	9	30	11	17	163	**133**
12	RSA1590	M	3	4	14	13	11	6	32	30	26	8	22	169	**137**
13	RSA1465	M	22	13	8	6	15	21	20	16	10	22	8	161	**139**
14	RSA1444	M	12	16	12	7	20	14	18	13	16	27	18	173	**146**
15	RSA1535	M	14	20	13	8	12	16	17	17	11	20	32	180	**148**
16	RSA1528	M	16	9	16	27	16	23	21	7	12	19	18	184	**157**
17	RSA1427	M	24	30	22	5	13	24	24	8	19	14	13	196	**166**
18	RSA1471	F	5	14	15	17	14	12	32	25	27	22	21	204	**172**

Figure 2.3. Example of scoring and overall results of a sailing regatta – fictional sail numbers and results (red number indicates discard).

An international Optimist sailing race course is laid in a trapezoid method (see Figure 2.4), which ensures the sailors race two upwind legs (start to mark 1; marks 3 or 3A to finish), one reaching leg (mark 1 to mark 2) and one downwind leg (mark 2 to mark 3 or 3A) in every race. A dinghy start involves a process of visual and auditory signals; sailors are required to keep all parts of their boat behind the start line (created by two anchored boats, at as close to a 90-degree angle to the wind as possible (Figure 2.4)) until the class flag has been lowered and a sound signal has been made. Having a successful start and sailing in a lane of wind unobstructed by other boats is deemed important for the outcome of the race (Araújo et al., 2015). All sailing races are unique as i) there is no defined track between the marks of the course and ii) the environment is unpredictable as the conditions of the course are always changing, i.e. wind direction, wind strength and waves are never identical. Furthermore, the total distance of the course changes as the environmental conditions change, for example in wind speeds averaging 6 knots (or 11.1 kph) the course distance will be shorter than if the wind speeds are averaging 16 knots (or 29.6 kph). Thus, a performance improvement is seen when the sailor improves their finishing position compared to their competitors rather than in sailing a shorter distance or time from previous performances. The decisions the sailors make as to how they chose to sail around the course, i.e. going to the right hand side to take advantage of an increase in wind speed or change in wind angle, are dependent on the sailors' skill at understanding and foreseeing the weather conditions as well as their technical and tactical understanding of the sport (Bojsen-Møller et al., 2015; Araújo et al, 2005). Although the course layout remains constant, each race varies in distance covered; since the sport relies heavily on environment conditions (Araújo et al., 2005), however the race officials aim to keep the sailing time per race as constant as possible.

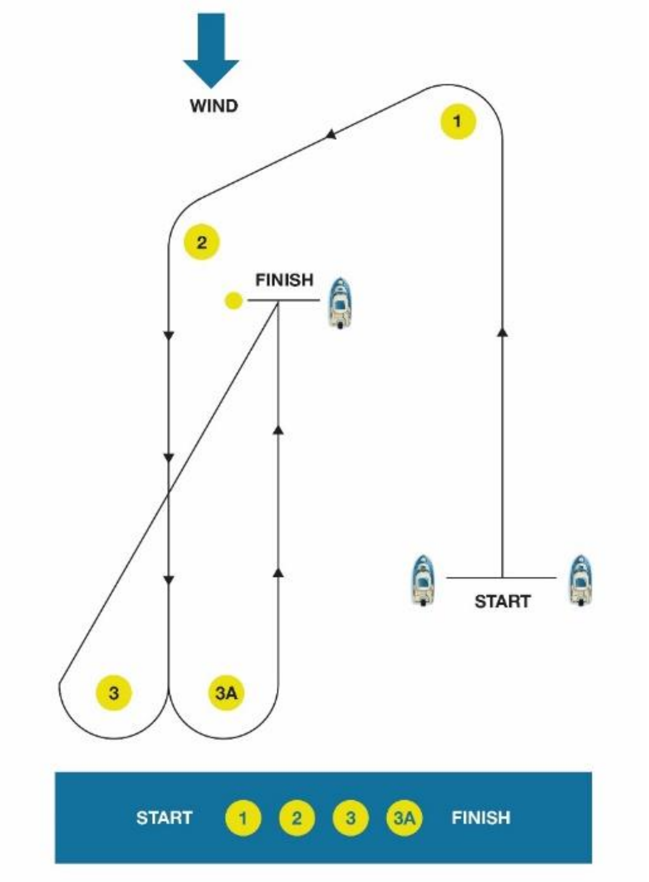


Figure 2.4. The International Optimist Dinghy Association (IODA) racing course. Illustration by Claire Walker and Sarah Ferreira (2019) ©.

In most cases children start sailing between the ages of eight and eleven years old (Palomino-Martín et al., 2017). The IODA Optimist World Championships, held annually, is the top tier regatta for high-level competitive Optimist sailors. This event has grown in popularity and competitiveness over the last five decades; with the inaugural event in 1962 involving participation from only four countries compared to the same regatta in 2019 where 65 countries were represented. Between 2014 and 2019, a total of 1537 sailors (1237 boys; 300 girls) from a range of 49-65 countries competed in the IODA Optimist World Championships; leading to an average of 256 sailors (80% boys; 20% girls) competing per year. All sailors compete together irrespective of age and gender.

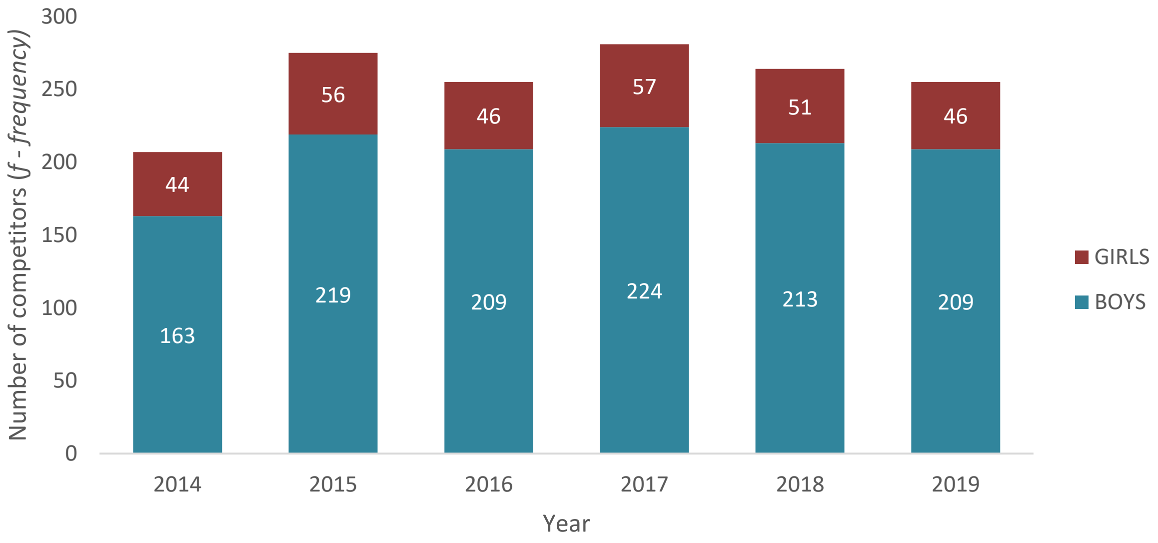


Figure 2.5. Frequency of participation in the IODA Optimist World Championships (2014-2019) (Claire Walker, 2019).

The IODA Optimist World Championships is held over eight days, which includes six days of individual racing and two days of team racing. Since 2014, the individual regatta consists of a maximum of twelve individual races, with the race committee aiming for a maximum of three races per day. Furthermore, a national or international race for the Optimist class dinghy is on average 50 minutes in length and consists of a start, upwind, reach and downwind legs, mark rounding's and a finish (see Figure 2.4) (IODA Race Management Policies, 2019).

Due to its unpredictable nature, the results of an individual sailor within a regatta often fluctuate (Ballegaard et al., 2016). As noted previously, sailing is scored based on position as the sailor crosses the finish line. Furthermore, sailing events are typically held over a number of days which also adds to the environmental challenge, as the wind may differ in strength and direction from one day to the next. It is one thing for the sailor to be good at sailing in light wind conditions; however, training should attempt to help the sailor improve their skill equally in different conditions. Thus, helping them to achieve similar or more consistent results in various conditions.

In conclusion, multiple variables (related to racing, movement patterns and sailing specific training) contribute to a better performance during a sailing race and subsequent regatta. While training is an important part of performance, the environmental conditions have a considerable impact on sailing. It is surprising that to date, only three studies have compared responses when sailing in different wind conditions. Therefore, it is important to consider the differences when sailors are training and competing in different wind conditions.

2.2.3 Optimist Sailing Performance

Previous research has confirmed that an athlete's body shape is a large determinant on performance in their chosen sport (Sinclair, Leicht, Eady, Marshall, & Woods, 2017; Gutnik, Zuoza, Zuoziene, Alekrinskis, Nash, & Scherbina, 2015). Therefore, it is unsurprising that the same can be said for high-level competitive Optimist sailors. For example, Palomino-Martín and colleagues (2017) studied the anthropometric characteristics of Optimist sailors competing at the highest level i.e. IODA OWC. The sailors (n = 180) were grouped according to their overall finishing positions in the 2003 IODA OWC; with the Top Group (TG) (n = 31) comprising sailors ranked 1 to 45 and the Fleet Group (FG) (n = 73) including sailors ranked between 135 and 220. The results showed that the TG were on average 14 years old, with the FG a year younger at 13 years. The authors suggested that this is related to the sailors' learning and maturity and that the skills and experience of the older sailors were a contributing factor to higher performance (Palomino-Martín et al., 2017). Furthermore, the TG sailors were heavier, taller and had more muscle mass compared to the FG. The findings of this study corresponded with the results of a study by Oliveira and colleagues (2011); that showed the senior division sailors were both heavier and taller compared to the junior division sailors.

Table 2.2 shows the sailing training reported in peer reviewed literature for Optimist sailors. Articles missing more than one piece of information were not included. This highlights the notion that experience, or number of years sailing plays a large role in determining the difference between better performing sailors and those in the non-elite or bottom rank.

Table 2.2. Optimist sailing training data published in peer-reviewed articles.

Author	Number of sailors	Age (years) (range OR mean ± SD)	Experience (years) (mean ± SD)	Training volume (hr/week) (mean ± SD)
Polato et al. (2007)	50	Infantile: 11-12	Infantile: 3.58 ± 1.12	NR
		Juvenile: 13-14	Juvenile: 4.15 ± 1.29	NR
Callewaert et al. (2014)	10	13.2 ± 1.0	NR	8.6 ± 2.7
Araújo et al. (2015)	15	12.1 ± 1.6	3.3 ± 0.7	NR
Callewaert et al. (2015)	23	Non-elite: 11.7 ± 1.1	Non-elite: 3.6 ± 1.8	Non-elite: 5.3 ± 1.9
		Elite: 13.6 ± 1.2	Elite: 4.3 ± 1.4	Elite: 9.8 ± 2.2
Lopez et al. (2016)	9	10.9 – 13.5	6.2 ± 0.8	9
Manzanares et al. (2015)	20	Bottom ranking: 10.0 ± 1.3	Bottom ranking: 1.3 ± 0.7	NR
		Top ranking: 13.2 ± 0.9	Top ranking: 5.2 ± 1.2	NR

*NR = not reported

2.3 Performance Analysis: Performance Indicators and Performance Profiles

Performance analysis is defined as a method "used to assess quality and/or quantity of performance data in an accurate and consistent manner" (Groom, 2012). Performance analysis is an area of sport science which is primarily concerned with observational analysis of actual sporting performance, with an aim to advance the current understanding of match or race behaviour in order to improve future performances and outcomes (McGarry, 2009; O'Donoghue, 2005). As such, performance analysis within sport science is unique, in that it only examines exactly what happened during actual performance. Within the performance analysis domain, knowledge on specific sport demands can be developed, factors associated with success can be determined, and the behaviour of athletes within the sporting context can be explained.

There is an increasing need for coaches to provide purposeful feedback to their athletes, specific information regarding the physical demand's athletes expose themselves to are becoming more popular; as well as being an integral part of the coaching process in elite sport (Nicholls, James, Bryant, & Wells, 2018; Hughes, 2008). An important component of any training program is the analysis, assessment, and feedback of the performance and training for athletes (Mäestu, Jürimäe, & Jürimäe, 2005); with an overall aim to improve sport performance (Hughes & Bartlett, 2002). With the advancement of technology as well as improved opportunities for data collection, specifically in sailing; reliable and objective data is more readily available to sport scientists and coaches (Farley, Harris, & Kilding, 2011; Hughes, 2008). Through which TLs, movement patterns and activity profiles via GPS tracking are able to be tracked in a live situation as opposed to in a laboratory setting (Groom, 2012; Farley et al., 2011). So far however, there is no scientific literature that has applied methods of performance analysis to sailing racing or training. This lack of attention is significant because more knowledge on this topic will be beneficial for many coaches and sailors during training for upcoming competitions, as well as during the respective regattas.

As mentioned earlier, for the purposes of this dissertation an individual successful performance is defined as a better race result when compared to the average results for that sailor in the respective regatta. In addition, success or failure of a performance should also be considered in the context of the performance, i.e. it is relative either to the opponent(s) or to previous performances of the team or individual (Hughes & Bartlett, 2002). The researchers, Hughes and Bartlett (2002) suggest that when investigating match or race classifications; the coach or sport scientist should always compare the team or individual's data with that of the opponent or if possible, with aggregated data from peer performances.

Determinants of competitive success at a junior sailing level may include psychological aspects, technical skill (boat handling), ability of reading the environment and the physical and physiological characteristics of the sailors (Callewaert et al., 2014). Some of these characteristics may be compensated for by others, such as an enhanced ability to read the environment can be compensated for with better boat handling skills. However, for a sailor to be successful they need to have a balance of all the above-mentioned skills, as well as an overall big picture understanding of the nature of the sport. In addition, sailing has a large strategic and tactical element, where races can be won or lost in a very short space of time. As a result, the consistency of the overall performance during a regatta is vitally important.

In order to provide useful feedback, sport scientists, performance analysts and coaches identify performance indicators (PI(s)) or descriptors of specific characteristics within the sport. If the appropriate PIs are defined and used, they may provide sport scientists and coaches with a valid means of performance interpretation. Once suitable PIs have been established, they can be used for the development of a performance profile. Performance profiling in the field of performance analysis is another component which has become popular in helping to compare athletic performances. A performance profile consists of pre-identified PIs, which when combined characterise the athlete or team's performance within the sport. Furthermore, a performance profile provides a description of the performance which leads to an improved understanding of the context of the competition (match or race) and may be used as a prediction of future performance. Both of these components (PIs and performance profiles) are important in a coaching context, however, little to no research has investigated their identification, development and utilisation in sailing.

2.3.1 Performance Indicators

Performance indicators are defined as a collection, or combination, of action variables that set out to describe some or all aspects of sporting performance (Hughes & Bartlett, 2002), as well as something that meaningfully contributes to a successful performance or race outcome. These indicators are most commonly used as a measure (i.e. positive or negative aspects) of an individual or team performances (within or between competitions) and sometimes used to compare performance to opponents, peers or previous performances.

When identifying PIs, consideration to prior knowledge of the sport, usually from someone who has either been competing or coaching in the sport for a long period of time or has an understanding of the variables which influence on the outcome of the event, match or race is needed. Performance indicators in sport are not stable to an individual or a team, as the performance in competition often varies with any new event, match or race (O'Donoghue, 2005). However, they are useful in that they can be used to help coaches and athletes determine areas within the sporting performance which can be improved, as well as being useful for general athlete monitoring. Furthermore, it is important to note that the PIs used for performance analysis must measure the critical aspects of performance in the sport.

A vast range of PIs exist, depending on the overall goal of the sport (like team sports where the aim is to score more points than the opponent, hockey, rugby, netball, basketball, soccer; or individual sports where you need to cross the finish line ahead of your opponents, running, cycling, swimming, sailing), the type of data (i.e. ratio or nominal), and the research question or motivation for the analysis (Hughes & Bartlett, 2002). Sailing involves numerous factors that determine performance; however, the sailor is ultimately judged on their final race outcome and accumulated points at the end of a regatta. A few PIs which have been determined through research include the sailors' boat handling, equipment and physical preparation, motor coordination, ability to 'read' and understand wind and weather conditions, as well as technical and tactical understanding of the sport (Bojsen-Møller et al., 2015; Callewaert et al., 2015; Bojsen-Møller et al., 2007). Few studies investigating PIs have considered actual performance of the sailors during competition, and objective race PIs (such as distance sailed, and time difference per leg) have not yet been identified for Optimist sailing. These should be investigated to establish more knowledge on a sailor's actual performance within a race.

In 2015, Callewaert and colleagues identified specific indicators of performance in junior dinghy sailors. Twenty-three male Optimist sailors were grouped into elite (n = 7) and non-elite (n = 16), and were required to complete anthropomorphic, physical and motor coordination tests. The results showed the elite sailors to be significantly older and sail more hours per week compared to the non-elite (see Table 2.2). No differences were reported in physical fitness, however the elite sailors performed significantly better in the motor coordination and sailing-specific tests compared to the non-elite sailors. The researchers suggest that the elite sailors gained more sailing specific experience (boat handling skills, tactical skills and environmental knowledge and understanding) because of their increased on-water training hours per week (Callewaert et al., 2015). In addition, it is suggested that strength- and speed-oriented coordination is an important indicator of Optimist sailing performance.

Hughes and Bartlett (2002) identify different categories of PIs, specifically i) match or race classification indicators, ii) technical indicators, iii) tactical indicators and iv) biomechanical indicators (Hughes & Bartlett, 2002). For the purpose of this dissertation, and since these seem the most straightforward and practical, only race classification indicators were considered. Some examples of race PIs in sailing include position at each mark, the time taken in each leg, the time difference from the leading boat at each mark, the distance sailed in each leg and overall and the velocity made good in each leg.

With the nature of sailing being so dependent on an unstable and relatively unpredictable environment, the PIs for the sport are fairly difficult to define accurately. In a team sport for example, it is often clear to see the success or failure in the performance on an action and how this can affect the overall outcome of the match. However, in sailing the performance outcome is overwhelmingly related to the decisions the sailors make; such as where they decide to start on the line, and how they decide to race up to the windward mark and around the course. A study by Legg, Mackie and Smith (1999) analysed the duration and frequency of various physical activities performed by Olympic class sailors during a simulated race. The researchers conducted a notational analysis using video recordings taken during each race and calculated the accumulated percentage of total time spent in various activities during both upwind and downwind sailing; specifically sitting, hiking (while trimming or pumping the mainsheet), rig adjustments, tacking and gybing. To date, no research has considered identifying or using PIs during an actual race. This may possibly be due to the practicality of assessing PIs during a race.

With this in mind, this dissertation will use race indicators in the form of position, time, time difference from leading boat, distance sailed, speed (average speed and top speed), velocity made good and speed over ground for the entire race and broke down into each leg.

2.3.2 Performance Profiles

With the identification of PIs, the formation of performance profiles is a natural progression. A PP is a collection of variables (typically pre-identified PIs) which characterise an overall performance of the athlete or team in question or the other competitors (O'Donoghue, 2005). The method provides coaches and athletes with objective data of what actually happened during a race as opposed to what they think happened and the purpose is to assess strategic and tactical movements, to ultimately improve performance.

In 2013, Butterworth and colleagues reviewed the literature on performance profiling, although four techniques were identified and discussed, the author concluded that more work is necessary to improve the presentation of information relating to competitive performance (Butterworth, O'Donoghue & Cropley, 2013). Some researchers have provided suggestions, for example on the number of events (i.e. matches/competitions) required to create a performance profile (Hughes, Evans & Wells, 2001), however there are criticisms for this, and most have only considered team sports. O'Donoghue (2005) proposed a procedure to determine a normative performance profile for different sports. This method was established to compare typical athletic performance as well as consistency of performance by standardizing the spread of performances using percentiles. The benefit of using percentiles is that the provided norms allow values to be associated with the percentile band they fall within, thus making it easier for a coach or athlete to compare the respective performance of an individual or team. O'Donoghue (2005) warned that researchers need to be aware of the outcome of the sport, specifically whether a lower or higher value indicates a better performance. This is important to take note of, since a lower rank or race result in sailing is deemed a better performance.

The first step in O'Donoghue's method involves determining percentiles (from, for example, 5% to 95% in increments of 5%) of the identified PIs from actual data sets. Following this, a normative performance profile of an individual can be constructed. Using the typical values presented, the individual's performance can be compared and presented in a radar chart. The usefulness of a performance profile is to help coaches, athletes and support staff to implement realistic goal setting strategies that focus on the key aspects of training and subsequent performance, as well as to help direct the athletes training towards the areas of perceived need. Butterworth and colleagues (2013) further suggest that performance profiling should be considered in context of coaching. The researchers suggested that the performance indicators selected during the development of the performance profile should have some practical value to coaches. The researchers also discuss the method proposed by O'Donoghue and Cullinane (2011), who suggest that the strength or quality of the opposition should be taken into account when building performance profile. This may be difficult to consider in the context of Optimist sailing, since these athletes do not acquire any manner of world ranking score.

Performance profiles can be produced for typical performances of athletes within the same competition or over several events, such as all the sailors competing in the same regatta. Or the data can be produced to illustrate the spread of performance for a single athlete; in sailing this may be a sailor performing over several days or over a few regattas. The information can possibly help to show whether a sailors' performance is consistent or erratic throughout the race and identify where this sailor can improve in order to see the biggest performance benefit. Furthermore, the information gained from a performance profile in sailing may possibly, indirectly assist in providing tactical and strategic information. Essentially the overall aim of a performance profile through PIs is to define the performance of an athlete against some form of outcome, be it previous performances, performances of other athletes or teams or the peer groups of the athlete in question (Hughes & Bartlett, 2002).

In spite of the obvious importance and influence the uncontrollable variables may have on a sailor's race and subsequent regatta performance, there is very little scientific literature on competitive race or regatta analysis in sailing. Some studies have attempted to simulate parts of a sailing race in a laboratory; however, the aim has been to analyse the physical and physiological characteristics of the sailors. Other studies have focused on the visual search strategies used by dinghy sailors in various parts of a race, such as the start (Araújo et al., 2015; Manzanares et al., 2015) and top mark (Pluijms, Cañal-Bruland, Hoozemans, & Savelsbergh, 2015). In general, the majority of research on sailing has focused on upwind sailing, and almost none on competitive performance in an entire race. Furthermore, no previous study has attempted to compile a performance profile for sailors.

Performance is influenced by several factors, specifically in sailing these include the environmental conditions and the level of the oppositions. In addition, sailing racing format is typically mass starts with numerous opponents; unlike the one-on-one settings we see in team vs. team or individual vs. individual opponent context (for example in netball and tennis, respectively). One possible way to contextualise the performance in sailing, would be to present race performance relative to previous performance and performance of the current leader or overall winner of the race. As this may allow the coach to determine in which part of the race their sailor may have performed better or worse. It is necessary to understand the associations between behaviours in context and performance outcomes (McGarry, 2009).

Therefore, the application value of PI and performance profiles in sailing is useful to understand areas of performance which require attention and can help decision making and preparation for future events. This is worth pursuing since these have not yet been investigated in Optimist sailors.

2.3.3 Performance Analysis and Performance Indicator Limitations

As the boundaries of sport are constantly being pushed, more attention has been given to improving the technology and techniques relating to collecting information from the athletes; specifically focusing on the activity analysis of athletes such as the type, intensity and frequency of activities performed (Wundersitz, Josman, Gupta, Netto, Gastin, & Robertson, 2015; Carling, Reilly, & Williams, 2009).

Important to note that performance analysis records what the players/sailors do at the time and does not record the other options that were available at the time; such as the decision a port tack boat makes to tack or to duck a boat approaching on starboard. It is also difficult to assess the success of the decision at the time it may have been made, only at the key points such at the marks is it possible to determine if the sailor gained or lost positions. Furthermore, the quality of the opposition has an impact in the decision likely to be taken as well as the execution of the action or movement. For example, a less skilled sailor may choose not to start next to a higher skilled sailor as there is a higher chance of the more skilled sailor out-performing them immediately at the start or within the first few hundred meters, thus forcing the sailor to tack away sooner than desired in order to find a lane of clean air and maintain boat speed.

2.4 Athlete Monitoring: Training Load

Training is defined as the manipulation of methods to induce adaptation, where an improved adaptation correlates with an improvement in sporting performance. This training-performance relationship is said to be a ‘dose-response’ (Lambert & Borresen, 2010; Gabbett & Domrow, 2007), where the optimal amount of training elicits a successful performance. In this dissertation, a successful performance, in sailing specifically, is considered as either “individual performance success” or “success in the sport”. Where individual performance success is defined as a race result better than the average results for that sailor in the respective regatta, and success in the sport is defined as a first, second or third overall rank (i.e. on the podium) achieved in a sailing regatta.

The training process should provide the athletes with the highest chance for adaptation (i.e. a suitable physical and technical stimulus) with minimal negative effects (i.e. maximum tolerable loads to improve fitness and cope with fatigue before injury or illness) to improve competitive performance. Due to individual variation, the maximum loads bearable differ between each athlete or the same athlete on different days, which is why individual athlete monitoring is of paramount importance in the training process (Borresen & Lambert, 2008). Furthermore, the training should be carefully monitored, whereby the planned stress imposed on the athlete is considered prior to any manipulation of training variables. Through appropriate athlete monitoring, a coach or sport scientist can determine whether an athlete is adapting to the training program (Halson, 2014), assess the current level of fatigue and determine the associated recovery process (Bourdon, Cardinale, Murray, Gastin, Kelmnaa, Varley, Gabbett, Coutts, Burgess, Gregson & Cable, 2017). Since athletes adapt differently to training and increases in training loads (TL(s)); where some can cope while others struggle to adjust (Kellmann, 2010); athlete monitoring is also necessary to minimise the risk of injuries and illness (Bourdon et al., 2017). Thus, the importance of developing an individualized load monitoring process cannot be overemphasized.

Rapidly developing technologies are adding to the opportunity of athlete monitoring in sport. New technology has further resulted in the monitoring process being more objective in nature and has provided an opportunity for analysis to be conducted in real-time. For example, with global positioning system (GPS) technology and mirco-technology (heart rate monitors) the data is much more readily available and easier to process.

2.4.1 Training Loads

Training load is defined as the amount of work an athlete performs during a given session, albeit training or competition; and consists of the relationship between external TLs and internal TLs. Whereby, external TLs can be defined as objective measures of the work performed (Bourdon et al., 2017), for example, the training volume, session type, distance covered, or power output. The internal TLs on the other hand, is usually a measure of the amount of stress imposed on the athlete either during a single session or over time (Borrensen & Lambert, 2009), measures include heart rate (HR), blood lactate [La] and session rate of perceived exertion (session-RPE). The training intensity is calculated using the athlete's relative intensity and the overall duration of the session. It may represent the TL of any endurance sport and can be calculated using valid methods, based on for example, HR or session-RPE (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, & Dodge, 2001). The primary reason for monitoring TLs of athletes is to see individual responses to training and competition, as well as to help to understand the fatigue/fitness ratio (Bourdon et al., 2017). In short, the internal TLs indicate the internal stress placed on the athlete by the external TLs (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2005). A coach or sport scientist can track (or monitor) the TLs over time to ensure the training stress does not become too great for the athlete.

Both load measures are important to help understand the athlete's TL and experts suggest that it is vital to take an integrated approach when monitoring load (Bourdon et al., 2017). For example, an athlete who completes the same session (i.e. 90 minutes of sailing) on different days may experience varying internal responses. Halson (2014) suggested that the relationship between internal and external load might help in revealing fatigue and whether the athletes are developing an injury or illness. Black and colleagues (2016) report that the understanding of an athletes' response to the demands of training and competition is vital, specifically since individuals respond to activity and training stimulus differently. The researchers go on to suggest that some methods used to monitor athletes, specifically those at the elite level, are problematic as these are relatively invasive in nature (for example blood sampling). Interestingly, very little research has investigated the effect wind intensities may have on the respective load experienced by sailors during training.

Table 2.3. Variables that have been used to monitor athlete training load and/or responses.

Measure	Variables	Training Load Category
Accelerations	Metres per second squared	External
Biochemistry and hormone analysis	Concentration, volumes	Internal
Blood lactate	Concentration	Internal
Body composition *	Total body weight, BMI, height	External
Distance *	Units of distance: metres, kilometres	External
Heart rate indices *	Average HR, time in zone, HR variability, TRIMP	Internal
Illness	Incidence, duration	External
Injury	Type, duration	External
Intensity *	Absolute, relative	Both
Frequency	Number of sessions per day, week, month, year	External
Neuromuscular tests	Countermovement jump measures	External
Power output	Absolute (watts), relative (watts/kg)	External
Oxygen uptake	VO2peak, VO2max	Internal
Perception of effort *	RPE	Internal

Perception of fatigue and recovery	Questionnaires: REST-Q, VAS, POMS	Internal
Repeat efforts	Number of efforts, quality of efforts	External
Sensations *	Hopeful, neutral, hopeless, enjoyment	Internal
Sleep	Quality, quantity, routine	Internal
Speed *	m/sec, knots	External
Technique	Movement deviations	External
Time or duration *	Overall duration of the session	External
Time-motion analysis	Time in sport actions, acceleration	External
Training type *	Modality, environment, equipment	External
Training volume *	Time, intensity	Both
Wellness questionnaires	Stress (sport & non-sport), anxiety, motivation	Internal

Adapted from Bourdon et al. (2017) and Halson (2014); * Variables to be used in the current study

Methods for Determining Internal TLs using HR and RPE

With advances in technology, it is becoming relatively easy and cost effective to quantify internal TLs using HR during a training session or competition (Borresen & Lambert, 2008). A fairly linear relationship has been described between exercise intensity and HR, where a higher HR corresponds to a higher Training Stress Score (Rodríguez-Marroyo, López, Avila, Jiménez, Córdova, & Vicente, 2003). Thus, HR monitoring has become an established measure for sport scientists, coaches and athletes to describe and monitor training intensities.

The HR measure can be expressed in relation to an individual's maximum HR (HRmax) which can be derived by either a maximal effort test or through the use of a theoretical calculation such as the one formulated by Tanaka and colleagues; HRmax = [208-(age x 0,7)] (Tanaka, Monahan, Douglas & Seals, 2001). Advantages of HR monitoring include continuous recording throughout a training session, immediate feedback if necessary and relatively easy access to the technology. In addition, HR monitoring is currently used in many sports to estimate the TL during training and competition sessions (Padilla, Mujika, Santisteban, Impellizzeri, & Goiriena, 2008).

Suggested methods of quantifying internal TL include the calculation of training impulses (TRIMP) and the session-RPE method developed by Foster and colleagues (2001). The training impulse methods have gained popularity, particularly due to the technical advancements of the HR monitors as well as when used in combination with performance analysis software (e.g. TrainingPeaks and Golden Cheetah). However, controversy over the validity of the method remains. Banister and Calvert (1980) were the first to propose the term TRIMP. The 'original' TRIMP is calculated using the duration and mean HR of a training session and an exponential weighting factor for intensity (Banister & Calvert, 1980). Edwards (1993), Lucía and colleagues (1999) and Manzi and colleagues (2009) modified the original formula as they thought best. Edwards' TRIMP (SHRZ) is calculated using five different zones, based on percentage of the maximum HR (HRmax), and weighting them with a linear intensity factor (IF) ranging from 1 to 5. The SHRZ method divides the training session into time spent in five HR zones (50-60%%, 60-70%%, 70-80%%, 80-90%%, and 90-100% of maximal HR). Duration in each zone is then multiplied by a weighting factor to account for the time spent in the higher and lower intensities, the adjusted scores are then summated (Borresen & Lambert, 2008; Edwards, 1993). Lucía's TRIMP is computed using three HR zones with a linear intensity factor (1–3). In this case, the zones are demarcated by the gas exchange threshold and the respiratory compensation point. In pursuit of further individualizing the TRIMP formuala, the individualized TRIMP derives an exponential weighting factor from the individual HR-lactate relationship which results in a different weighting factor for each HR point. (Vermeire, Vandewiele, Caen, Lievens, Bourgois & Boone, 2019).

Rating of perceived exertion (RPE) is defined as the athletes' conscious sensation and awareness of the level of physical strain on the body, or "how hard the body worked", relative to the combined physiological, biomechanical and psychological fatigue imposed on the athlete (Buchheit & Laursen, 2013). It has been well established that RPE is strongly related to HR, where 1 RPE score (Borg RPE scale 6-20) (Borg, 1998) approximates to 10 bpm (Scherr, Wolfarth, Christle, Pressler, Wagenpfeil, & Halle, 2013). Furthermore, RPE has been deemed a valid and reliable measure of intensity (Haddad, Stylianides, Djaoui, Dellal, & Chamari, 2017; Wirnitzer & Kornex, 2008). In 2001, Foster and colleagues proposed a session-RPE method, which takes into consideration the intensity and duration of a single exercise bout, albeit training or competition, to quantify the internal TL of the athlete. To calculate the internal TL an athlete is asked to score the session according to the modified CR-10 scale (see Figure 2.6) (Foster et al., 2001). This value is based on the athletes perceived feeling of the training session or entire competition's training intensity. The value given to TL is expressed as a single arbitrary unit (A.U.) and calculated by multiplying the training intensity (sRPE score) by the total duration of the session (minutes). For example, an athlete gives a sRPE score of 7 (Very Hard) for a 64-minute session; the resulting TL is 448 A.U.

Session-RPE has the potential and scientific support to affect a large proportion of the global sporting community. It is an inexpensive and simple tool to use and report on; highly practical and reliably (Haddad et al., 2017) measures the outcome of an individual athlete's performance or effort during training or competition. In addition, this method has been shown to help in performance optimization by providing coaches and sport scientists with a quantified score relating to the subjective feelings of the athletes towards the training session as a whole

(Haddad, Padulo, & Chamari, 2014; Morgan, 1994). In summary, the session-RPE tool for athlete monitoring is an affordable, practical and valid tool for monitoring and prescribing exercise intensity; independent of age, activity type and performance level (Scherr et al., 2013).

Rating	Descriptor
1	Really easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal

Figure 2.6. Rating of Perceived Exertion modified CR-10 scale (Foster et al., 2001).

The use of technology in athlete monitoring has contributed to the understanding between the differences in individual TL and intensities during training, as well as live game play in many team sports. However, very few studies have focused on the use of micro-technology for the analysis of TL and intensities in surface water sports. This may be because the equipment is expensive and the chance that it does not work in those environments is relatively high.

2.4.2 Training Load and Injury Relationship

One of the most reported reasons for athlete monitoring is to reduce the risk of injury. Athletic injuries are mostly the result of a general lack of fitness, overuse, overtraining or traumatic accidents (Skarp, 2009). In sailing, knee and back injuries are the most commonly reported and cited by sailors (Bøymo-Having et al., 2013; Skarp, 2009). Additionally, monitoring athletes and their TLs have been deemed important through recent research supporting a positive relationship between an athletes TL and injury rates (Bowen, Gross, Gimpel, & Li, 2017; Gabbett, 2016).

A recent study by Kostański, Frąckowiak and Pospieszna (2019) explained that back pain occurs frequently in Optimist sailors during sailing (specifically during the hiking position) and during on-shore activities (such as lifting the hull or sail during rigging). Of the 84 sailors, 43%

reported having some level of back pain within the training season. The study also considered coaches thoughts on training and load in Optimist sailors. The majority of the coaches (67%) mentioned including some level of specific strength and conditioning exercises in addition to on-water sailing training to help the sailors prepare for the physical demands of the sport.

In 2013, Bøymo-Having and colleagues presented their study on dinghy sailors' training habits, injury incidence and type of injury. The researchers compared the reports from 24 Swedish sailing team members and 21 club sailors over a period of 12 months. The sailors were required to keep a training diary, including all on- and off-water training, as well as to report this training and any injuries through a web-based questionnaire. The reports were completed at the end of every month. The results showed no difference in on-water training between club sailors and those in the Swedish sailing team, however the sailors in the Swedish sailing team performed significantly more off-water training compared to the club sailor ($p = 0.006$). A total of 144 injuries were reported over the 12-month period. The researchers concluded that injuries occurred most often during off-water training and activities, with the least amount of injuries occurring during sail training and racing.

Most importantly, lack of training, too much training and/or poor technique are the most common factors leading to injury (Kostański et al., 2019). As such, more knowledge on the load's athletes are exposed to during the sport, as well as teaching proper technique to reduce the load through for example the lower back, is necessary.

2.4.3 Current Application of Athlete Monitoring and Training Load Methods in Sailing

In the past it was common to gather information relating to athlete monitoring through observation and taking notes with pen and paper. This method is very time consuming, both during the session and once the athletes have gone home. The data still required processing, evaluation and analysis before being compiled into a report. With modern technologies and applications, the process of athlete monitoring has become far more efficient and time saving for coaches and sport scientists.

Limited studies have specifically set out to investigate TLs of sailors, moreover most of these studies have reported the number and types of injuries the sailors gained over time. In 2016, Lopez and colleagues investigated cardiovascular and metabolic responses of Optimist sailors for two 15-minute on-water upwind sailing conditions. During the condition involving tacking the average HR was 128 ± 22 beats per minutes (bpm), while the average for the condition involving no tacking amounted to 130 ± 20 bpm, indicating no difference between the two. The reported wind speeds during the conditions ranged from 3.6 to 9.3 metres per second (7 to 18 knots).

Identifying the relationship between the training environment and the competition requirements will help coaches design training programs that maximize performance in competition. During sailing training and racing, all the demands of the sport must be met (for example physical fitness, sport specific knowledge) while considering the environmental changes and the sailors' position relative to their opposition and the course. Given this, the training process should provide different physiological, technical, tactical and strategic stimuli to allow for maximum adaptations to meet the specific requirements of competition (Torres-Ronda et al., 2016).

A comprehensive knowledge of the specific environmental demands, as well as how they change with a change in environment, during sailing training sessions and competition is central for a better understanding of the physical and physiological loads the sailors are exposed to (Torres-Ronda et al., 2016). Keeping this in mind, the current dissertation will consider the following measures to determine external TL: body composition, distance, training volume, training type (where a measure of wind intensity was included). These external TLs were measured to determine how much work the athlete is performing during the training session. In addition, HR indices, training intensity, perception of effort and sensations (specifically enjoyment) were used to measure the internal TLs of Optimist sailors. These variables were used to quantify the overall stress of a sailor during training in various wind intensities.

2.4.4 Athlete Monitoring and Training Load Criticism

A few criticisms to the research, testing methods and application of training intensities have been suggested. Firstly, that the application of the research towards to monitoring of high performing athletes may be going too far, almost to the point that the athletes can no longer enjoy being themselves when they are off the training field. In that they are now being monitored continuously as opposed to just during training or matches.

Furthermore, mental factors may impact the interaction between TL, performance and injury. For example, issues when using only subjective TL monitoring methods may involve a lack of separation between biomechanical, physiological and cognitive load (Coyne, Haff, Coutts, Newton, & Nimphius, 2018). In addition, it is important to note, that while internal TL methods have been used with youth athletes, these measures should be applied with caution. The youth athletes may not yet have the ability to accurately assess their perception of exertion following an exercise session (Bourdon et al., 2017). To minimise these effects, it is necessary to link subjective scores to objective measures.

2.5 Problem Statement

In comparison to many other sports, very few studies have investigated the PIs and training demands of sailing. Specifically, there have been no on-water studies exploring the session demands of Optimist sailing in various environmental conditions. Additionally, the laboratory-based research in sailing is predominantly focussed on the “hiking” technique, with relatively few studies examining more than one component of the sport (i.e. more than the start or upwind leg).

Furthermore, limited scientific knowledge is available in sport science and sailing; specifically, when it comes to TLs and PIs during training sessions and actual race situations. This translates into even more restricted knowledge regarding athlete monitoring, performance management and the enhancement of subsequent training techniques in sailing. Therefore, studies that examine the PIs in an Optimist sailing racing context are required. While, methods for monitoring training and determining the respective session TLs are also needed so the training program and athletes can be sensibly monitored. Although various methods of monitoring exercise intensity and TL exist, in most cases sport scientists or coaches are limited to the most practical and financially feasible methods. For real-time training and competition monitoring, GPS, HR and RPE measures fit both criteria.

In sailing, the coach can manipulate training though the frequency, duration and intensity of the sessions, while the load is dependent on the sailor’s initial fitness level, performance level, available training time and the amount of time to the targeted event. Furthermore, sailing training and load may be affected by the weather conditions which the sailors train or compete in. Thus, quantifying the TLs is important as it allows the sport scientist, coach or trainer to evaluate the training stress on the athlete in various sessions. Consequently, this observational study may provide information into these differences.

Information pertaining to the TLs and PIs of Optimist sailors is important in helping the coaches and support staff to understand the nature of training the athletes should be undertaking in order to be racing competitively. The TLs and PIs of the sailors will be measured with micro-sensors (specifically GPS and HR monitors) and sRPE measures. The GPS units will be used to identify potential within race PIs, while the sRPE and HR measures will quantify the TLs of competitive South African Optimist sailors in different wind intensities.

The IODA Optimist World Championship regatta is highly competitive and a good indicator of future sailing performance and or level, with many Olympic, Americas Cup or Volvo Ocean Race sailors once having competed in the event (IODA, 2004). With the development of sport science knowledge and an increase from most high performing athletes in the use of a scientific approach to the design, implementation and monitoring of training programs.

To the researcher's knowledge, no consensus on a measuring tool for TL in sailing has been reported in the literature. The reason for this may be twofold, firstly that the correlation between training factors and corresponding physical and physiological responses are highly individual and may differ between sailing class and/or role on the boat; or that research has yet to considered the implications of differences in TL during varying environmental conditions and the effect this may have on sailing training at a youth level.

Consequently, the purpose of the current research is to contribute to the literature identifying relevant Optimist sailing race PIs, as well as quantifying the TLs of Optimist sailors. The application of this information is valuable to sailors and coaches, respectively. We hope to provide insights into the training methods, evaluation of techniques and performances and influence of external stimuli, which can be used to enhance the performance of Optimist sailors at the respective regattas. Furthermore, the data gained from this investigation may possibly be used for scientific program development purposes.

2.5.1 Research Question & Aims

What are the race performance indicator(s) and acute training load requirements of competitive* Optimist sailors?

Primary aims

The primary aims of this research are i) to determine the race performance indicator(s) of high-level* Optimist sailing races and ii) to quantify the training loads within different wind intensities of competitive South African Optimist sailors.

Secondary aim

The secondary aim is to develop an Optimist race performance profile from the IODA Optimist World Championships.

*Competitive high-level Optimist sailors refers to an individual who participates in an organized team or individual sport that requires regular competition (at elite or national and international level) against others as a central component, places a high premium on excellence and achievement, and requires some form of intense systematic training (adapted from the 36th Bethesda conference) (Maron & Zipes, 2005).

Table 2.4. Dissertation research objectives.

Chapter	Research Objectives
2	Narrative review on existing training monitoring and performance indicators research on Optimist sailing.
3	Scoping review on the methods that are currently used for athlete monitoring in environmentally powered/non-motorised surface water sports.
4	Identify race performance indicators used in Optimist World Championship sailing racing and create a race performance profile from these performance indictor variables.
5	Quantifying training loads of high-level competitive South African Optimist sailors in different wind intensities.
6	Conclusion, as well as contribution and application of findings.

2.5.2 Variables

Chapter 3: Article One

Independent variables:

Race

Performance level: final series (gold, silver, bronze, emerald)

Dependent variables:

Position at the respective marks (mark 1, mark 2, mark 3) (see Figure 2.3)

Position change (gain or loss) during each leg

Total race time (minutes)

Time per leg (minutes)

Time difference from race leader at each mark and the finish (seconds)

Velocity made good (VMG) in each leg (knots)

VMG difference from the race winner in each leg (knots)

Total distance sailed (metres: m)

Distance sailed per leg (m)

Top speed (knots)

Average boat speed during different sailing legs (upwind, reach and downwind)

Speed over ground per leg (knots)

Categorical variables:

Sex

Chapter 5: Article Three

Independent variables:

- Training session
- Environmental conditions: wind intensity (light, medium, strong)

Dependent variables:

- Energy expenditure (AU)
- Heart rate (HR) (beats per minute): minimum HR, HR during exercise, peak HR, HR reserve
- Training Impulse (TRIMP) (AU)
- Summated-heart-rate-zone (SHRZ) (AU)
- Session-RPE (AU)
- Duration of a training session (minutes)
- Wind speed (knots)

Categorical variables:

- Age
- Body weight (kg)
- Sailing experience (years)
- Average hours of training per week

CHAPTER 3: ARTICLE ONE

Race Performance Indicators and Profiles for Optimist Sailors in the IODA Optimist World Sailing Championships between 2014 and 2018

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Abstract

The development of a race performance profile is essential to compare an athlete's performance to their past performance and/or to relate their performance to that of the relevant population. The primary aims of this paper were to (i) identify race performance indicators (PIs) in high-level Optimist sailing races; (ii) use the identified PIs to determine race performance profiles for Optimist sailors competing in the IODA Optimist World Championships (OWC). Data from a total of 150 races (qualifying series: n = 90; final series: n = 60) were collected and analysed from five IODA OWC regattas (2014-2018). The relationship between 36 variables and race outcome for all races (irrespective of the fleet) in the qualifying series, as well as for the gold, silver, bronze and emerald fleets in the final series, were considered. Optimist race performance profiles for IODA OWC races were built, using variables ranked highest based on coaches' input and those that were significantly associated with higher race rankings. The PIs identified for the performance profile included the position at each mark, position change in all legs, VMG per leg, VMG difference from race winner per leg, time in each leg and overall, the time difference from the race leader at each mark, and distance sailed (per leg and overall). Furthermore, in order to be in the top group of finishers in the gold fleet during the qualifying series, a sailor should aim to be within 122 seconds of the race leader at mark 2 and within 124 seconds at the finish. Relating a sailor's performance to the percentile-based profile can indicate their performance level in comparison to other Optimist sailors competing in IODA OWC races; this not only considers final finishing position but may also lead to a more practical interpretation of the overall race performance.

Keywords: *performance profile, percentiles, race performance indicators, Optimist sailing*

3.1 Introduction

Performance analysis is primarily concerned with actual athlete performance during typical sport training and competition [1]. This analysis assists coaches to identify aspects of the athlete's performance that can be improved, and to provide appropriate objective feedback, which supports decision-making and ultimately enhances and develops sporting performance [2-3].

A performance profile is a set of performance indicators (PI(s)) with values based on an athlete's typical performance during a race rather than a single performance [4]. Where PIs are the combination of action variables that aim to define an aspect of performance, albeit training or racing [5-6]. For this study, race PIs are defined as action variables relating to the outcome of decisions made and skills during an actual competitive performance. Performance profiles have been used in sports such as tennis [7-8], rugby union [9], netball [10] and soccer [11]. To date, no research has investigated nor developed performance profiles for surface water sports during an actual competition.

The purpose of performance profiling is to compare an athletes' or teams' performance to a) their previous performance, b) the athletes' peers, and c) other competitors in a match or race [8-9,11]. Therefore, the identification of PIs is necessary to recognize what can be compared and what should be considered in the development of a sport's specific performance profile. Accordingly, as suggested by previous researchers [4,12] an understanding of an athlete's performance, in this case, a sailor, needs to consider multiple performances before norms can be established. This is relatively straightforward in sailing, as a regatta is constituted after a minimum of four races being sailed. However, in sailing, there are two external influences which most likely would affect race performance; specifically, (i) the environmental conditions (i.e. wind intensity, waves, currents, temperature, humidity) [13]; and the (ii) impact of the other competitors in the race (i.e. their performance level and actions) [14].

A few PIs have been mentioned in previous sailing research, such as strength- and speed-orientated motor coordination [15-16]. However, these are biomechanical PIs and as a result are very difficult to analyse during a race. Therefore, the present study considered specific, objective race PIs, which can be accessed during high-level Optimist regattas and that can be used by Optimist sailing coaches. The interpretation of the selected race PIs, in sailing, can be done by comparing the values achieved by the individual sailor to those obtained by the race leader in the same race (thus negating the change in environmental conditions over the course of a day); or by relating their values to the distribution of performances of the relevant population.

The International Dinghy Association (IODA) Optimist Sailing World Championships (OWC) is held every year and represents the highest level of competition for Optimist sailors. Optimist sailing is most often contested during fleet races, which involve a mass start, followed by a sprint race around a series of marks. Where the objective of every sailor is to cross the finish line ahead of their opponents, with the resulting overall position aiming to be as low as possible (i.e. to finish ahead of as many opponents as possible). It is important to highlight that the scoring system used in Optimist sailing determines a better performance as a lower score or race outcome. This format negates the impact of time, as results are determined based on which sailor was the first to cross the finish line irrespective of the time taken [17].

Due to the nature of the sport, limited objective information is available regarding sailing performance within a race. A better understanding of the nature of the race, as well as a method to quantify the impact of PIs in sailing, is a valuable exercise. As this may identify differences in the skill level of sailors during a race or it may become a tool, coaches use to provide objective feedback to the sailors based on their performances. Therefore, in the present study, we sought to provide sailing coaches with information that would assist their understanding of the relative importance of performance within each leg of a high-level Optimist sailing race. Currently, very little research focuses on sailing performance during an actual race, even more so from a performance analysis perspective. Furthermore, no research has undertaken to provide a performance profile relating to sailing performance, specifically in an Optimist dinghy.

The primary aims of this investigation were to (i) identify relevant race PIs and (ii) use the identified PIs to determine a performance profile, for high-level Optimist sailors competing in the IODA Optimist World Championships (OWC) (2014-2018). Thus, in addressing these aims, this investigation endeavours to consider the techniques currently used in the development of performance profiles and establish a performance profile (using percentiles) for Optimist sailors competing at the IODA OWC.

3.2 Methods

For this retrospective descriptive study, 36 performance indicators (PIs) were initially identified based on the information available from the global positioning system (GPS) tracking units. After that, twenty-two international sailing coaches were asked to rank the PIs according to most useful and appropriate; sixteen coaches responded (73% response rate). The method described by O'Donoghue [14] was used to establish a performance profile, using percentiles based on IODA OWC race performance indicators. Following this, the PIs were analysed to determine if any could be predictors of the final finishing race position.

Since all the information used for this study is available in the public domain, only ethical approval for publication purposes was required and approved by the institutional review board (REC SBER Project number: 3273). Written informed consent from individuals was not sought because no individuals were named. An independent researcher furthermore anonymised data and all personal information were excluded.

Races Analysed

In total, 150 races (i.e. qualifying series = 90, finals fleets: gold = 17, silver = 17, bronze = 15, emerald = 11) from five IODA Optimist World Championships regattas (2014-2018) were used for analysis. Only performances where the sailor completed the whole race were included, while incomplete or corrupted data was removed from the analysis (n = 237). Subsequently, a total of 9937 data points were included in the final analysis.

Data Collection and Extraction

After consideration of the coach's responses as well as significant associations of PIs with the final finishing race position ($p < 0.01$), 36 PIs (Table 3.1) were identified for the sailing race analysis. Also, those PIs highly associated with each other were excluded.

Table 3.1. Description of all the initial race performance indicators.

Performance Indicator	Description (units of measure)
Position m1	Position at mark 1 (rank).
Position m2	Position at mark 2 (rank).
Position m3	Position at mark 3 (rank).
Position change m1-m2	The positional change (gain or loss) between mark 1 & 2 (rank).
Position change m2-m3	The positional change (gain or loss) between mark 2 & 3 (rank).
Position change m3-finish	The positional change (gain or loss) between mark 3 & the finish (rank).
VMG leg1	Velocity made good during leg 1 (kts).
VMG leg2	Velocity made good during leg 2 (kts).
VMG leg3	Velocity made good during leg 3 (kts).
VMG leg4	Velocity made good during leg 4 (kts).
VMGdiff leg1	The difference in VMG between the race winner during leg 1 (kts).
VMGdiff leg2	The difference in VMG between the race winner during leg 2 (kts).

VMGdiff leg3	The difference in VMG between the race winner during leg 3 (kts).
VMGdiff leg4	The difference in VMG between the race winner during leg 4 (kts).
Time leg1	The time taken in leg 1, upwind (min).
Time leg2	The time taken in leg 2, reach (min).
Time leg3	The time taken in leg 3, downwind (min).
Time leg4	The time taken in leg 4, upwind (min).
Race time	The total time taken to complete the course (min).
Time difference m1	The time difference from race leader at mark 1 (s).
Time difference m2	The time difference from race leader at mark 2 (s).
Time difference m3	The time difference from race leader at mark 3 (s).
Time difference finish	The time difference from race leader at the finish (s).
Distance leg1	The distance sailed in leg 1 (m).
Distance leg2	The distance sailed in leg 2 (m).
Distance leg3	The distance sailed in leg 3 (m).
Distance leg4	The distance sailed in leg 4 (m).
Total race distance	The total distance sailed during the race (m).
SOG leg1	Speed over ground in leg 1 (kts).
SOG leg2	Speed over ground in leg 2 (kts).
SOG leg3	Speed over ground in leg 3 (kts).
SOG leg4	Speed over ground in leg 4 (kts).
Top Speed leg1	Top speed recorded in leg 1 (kts).
Top Speed leg2	Top speed recorded in leg 2 (kts).
Top Speed leg3	Top speed recorded in leg 3 (kts).
Top Speed leg4	Top speed recorded in leg 4 (kts).

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; kts: knots; min: minutes; sec: seconds; m: metres; SOG: speed over ground

The 2014 to 2018 IODA Optimist World Championships data for the PIs were collected from the TracTrac website (www.tractrac.com;TracTrac APS, Lyngby, Denmark). The GPS devices (Queclink GL300, Shangai, China) used during the races, sample the position every 1-3 seconds and are capable of logging the position of the boat for between 5 and 6 hours on a single charge. The device has a reported position accuracy and precision (circular error probable) of < 2.5 meters (www.queclink.com/GL300). A device was placed in a waterproof bag and then secured onto the right buoyancy bag on each boat. Race data (GPS and overall results) were gathered from the official internet sites in 2019 (www.optiworld.org/default/events/ioda/ini/1 accessed on 24/04/2019 and www.tractrac.com/web/events-list/ accessed on 02/05/2019).

The GPS dataset consisted of raw time measures for each leg of the race (4 legs) collected as the sailor rounded the respective mark, position at each mark and distance sailed in each leg (see Figure 2.4). Raw time data records were processed by converting them from hh:mm:ss to minutes; differential times were calculated as the difference between the times each sailor rounded the respective mark and the current leader of the race at that point (being zero). Time and position gained or lost were also calculated at each mark of the course. Velocity made good (VMG), VMG difference from race leader was calculated, speed over ground (SOG) and top speed were also determined. No physical data was taken concerning the total distance of the racecourse, as this varies according to wind intensities. However, race officers have access to an Optimist speed chart which provides information relating to the suggested leg length (in nautical miles) based on the average wind range (in knots), to ensure the races meet the target sailing time of 50 minutes (IODA Race Management Policies, 2019) (See Appendix H).

Statistical Analysis

Data were initially exported into Microsoft Excel® (Office 2010, Washington, USA). Once all the data were processed and checked for anomalies, statistical analysis was completed using Statistica version 13.5.0.17 (TIBCO Software Inc., California, USA). A Shapiro-Wilk test was conducted to address the normality of the data; all PIs were found to be normally distributed. Descriptive data are reported as mean ($\bar{x}$) ± standard deviation (SD), and deciles used for the performance profiles. The data were split into the qualifying series, and the various fleets for the final series (i.e. gold, silver, bronze and emerald). Spearman rank correlations determined the correlation coefficient between all PIs and final race position. Correlations were categorised according to the following thresholds; *rho* = <0.10 = negligible, 0.10-0.29 = small, 0.30-0.49 = moderate, 0.50-0.69 = large, 0.70-0.89 = very large, 0.90-0.99 = nearly perfect, 1.0 = perfect [18]. Alpha level was set at 0.05. Only correlations ≥ moderate strength were considered for the best subsets regression and Classification and Regression Tree (CART) methods.

The machine learning, CART method was employed as a predictive algorithm model. This method makes use of a decision tree to explain a target variable's values (i.e. race outcome) which can be predicted based on other values (i.e. a selection of race PIs). In the decision tree, each fork is a split in a predictor PI variable and each node at the end has a prediction for the race outcome [19]. Finally, the best subsets regression method was applied to identify useful PI predictors of race outcome. Best subsets compare all possible models using a specified set of predictors and display the best-fitting models. For the performance profile, the selection of PIs are incorporated into percentile bands (in deciles) based on O'Donoghue's [14] method; since no world ranking exists for Optimist sailors and due to the mass start format (with more than one opponent competing at a time), the regression-based method by [20] could not be applied. However, by splitting the results into qualifying and final series (i.e. gold, silver, bronze and emerald fleets) the relative quality of the opponents would be standardised across fleets.

3.3 Results

The IODA OWC regatta is held at a different venue every year, this may influence the environmental conditions during the specific event. However, the environmental conditions were similar across all events (Table 3.2).

Table 3.2. Descriptive characteristics of the IODA OWC (2014-2018).

Year	Venue	No. sailors	Temperature (°C)	Wind speed (knots)	Humidity (%)
2014	Argentina	207	24.3 ± 2.6	9.7 ± 4.9	66 ± 12
2015	Poland	275	20.2 ± 3.2	6.8 ± 1.5	54 ± 12
2016	Portugal	255	24.8 ± 1.9	8.8 ± 1.4	67 ± 9
2017	Thailand	281	30.4 ± 1.2	4.0 ± 2.6	70 ± 6
2018	Cyprus	264	30.7 ± 0.9	11.9 ± 2.7	60 ± 6
	Average ± SD	*256 ± 29*	*26.08 ± 4.5*	*8.2 ± 3.0*	*63 ± 6.4*

Most coaches (f = 16) ranked the VMG difference between the sailor and race winner, position change between marks and position at each mark as being the top three most useful PIs based on the available information. The VMG in each leg, time difference from the leading boat and distance sailed in each leg, were also rated among the more useful PIs. With time taken to complete each leg, top speed and total race time being rated as least valuable.

From the statistical analysis, PIs for the regression analyses were identified in a serious of distinct steps. The selection of PIs originally included did not differ over the years ($p > 0.05$) and was consequently pooled together for additional statistical analysis. The final race outcome (rank) was converted to a relative position in relation to the number of sailors participating each year.

Results of the correlation matrix revealed almost perfect correlations between positions at marks 1, 2, and 3 and race outcome for all qualifying series races (*rho* = 0.96 - 0.98, p <0.01) and all fleets in the final series (*rho* = 0.93 - 0.97, p <0.01). As a result, these were not included in the subsequent regression analysis, but are included in the performance profile.

Similar relationships were found in the qualifying series and the final series, where the time difference between current race leader at mark 1, 2, 3 and final position (*rho* = 0.72 - 0.86, p <0.01) showed large correlations with the race outcome.

The difference in VMG from race winner over leg 1 for the qualifying series (*rho* = 0.71, p <0.01) and in the final series i.e. gold (*rho* = 0.57, p <0.01), silver (*rho* = 0.70, p <0.01), bronze (*rho* = 0.75, p <0.01) and emerald (*rho* = 0.69, p <0.01) fleets showed large to very large correlations. While the difference in VMG from race winner over leg 4 for the qualifying series and all the fleets in the final series showed moderate correlations (*rho* = 0.35 – 0.42, p <0.01).

Understandably the total time, but only over the final series, correlated somewhat with final race outcome over all fleets (*rho* = 0.30 – 0.40, p <0.01). While the time in leg 1 indicated similar moderate correlations (*rho* = 0.31 – 0.37, p <0.01) except for the emerald fleet (*rho* = 0.29, p <0.01).

Five decision trees were created, one for each final race outcome (specifically for qualifying series, as well as gold, silver, bronze and emerald fleets). The CART method mostly mirrored the correlations and confirmed the most important PI predictors were time difference from race leader at marks 1, 2, 3, and the finish, as well as difference in VMG from race winner over leg 1 in both the qualifications and finals. The five variables were inversely associated with less or more time leading to a higher or lower rank for final race outcome.

The training set in the CART analysis further revealed that in order to be in the top finishers of sailors during a race in the qualifying series, the sailor should be within 117.5 seconds of the race leader at the second mark and 128.5 seconds by the finish line. While anything more than 117.5 seconds of the leader at the second mark, and more than 0.25 kts VMG difference from race winner during leg 1 will certainly result in bottom positions. These times differ slightly in the final series, in the gold (Top positions: ≤ 121.5 seconds difference from race leader at mark 2 and ≤ 123.5 seconds difference from race leader at the finish; Bottom positions: > 121.5 seconds difference from race leader at mark 2 and > 221.5 seconds difference from race leader at the finish), silver (Top positions: ≤ 158.5 seconds difference from race leader at the finish; Bottom positions: >158.5 seconds difference from race leader at the finish and >

0.25 kts VMG difference from race winner during leg 1), bronze (Top positions: (≤ 107.5 seconds difference from race leader at mark 2; Bottom positions: > 107.5 and 139.5 seconds difference from race leader at mark 1 and 2, respectively), and emerald (Top positions: ≤162.5 seconds difference from race leader at the finish; Bottom positions: >162.5 seconds difference from race leader at the finish) fleet.

Table 3.3 provides an overview of the best subsets regression results; all PIs included significantly predicted race outcome ($R^2 \geq 67\%$; $p < 0.05$), appeared in at least 10 out of the 20 best prediction models.

Table 3.3. Summary of best subsets regression variables.

Qualifying	Gold	Silver	Bronze	Emerald
VMGdiff leg1	VMG leg3	VMG leg2	VMGdiff leg1	VMGdiff leg3
Time leg1	VMGdiff leg3	VMGdiff leg2	VMGdiff leg2	VMGdiff leg4
Time leg2	Time leg2	VMGdiff leg3	VMGdiff leg3	Time leg1
Time leg4	Time leg3	Time leg2	Time leg3	Time leg4
Time difference finish	Time difference m1	Time leg4	Time leg4	Time difference m3
Total distance	Time difference finish	Time difference m3	Time difference finish	Distance leg1
	Total distance	Distance leg4	Distance leg3	SOG leg1
			SOG leg3	

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; kts: knots; min: minutes; sec: seconds; m: metres; SOG: speed over ground

Table 3.4 shows the performance profile for all the races in the qualifying series (2014-2018), whereas, Tables 3.5, 3.6, 3.7, 3.8 show the race performance profile for the final series, as they are split in the respective fleets. These were considered according to the fleets to account for the level of competition. In that, the best sailors in the IODA OWC in that year qualify in the gold fleet, followed by silver, bronze and the bottom-ranked sailors in the emerald fleet. A negative value in the position change between marks shows an improvement in performance since the sailor is gaining positions in that leg, thus, improving their overall race result. While a positive value indicates a loss of position, contributing to a more mediocre race result.

Table 3.4. Performance profile for the qualifying races during IODA Optimist World Championships from 2014 to 2018 (n = 90 races).

ALL FLEETS	90%	80%	70%	60%	50%	40%	30%	20%	10%
POSITION									
Position m1	8.5	15.1	21.5	27.6	35.9	42.4	48.7	55.5	60.7
Position m2	8.4	14.4	21.7	29.9	35.8	42.4	49.0	56.0	61.2
Position m3	8.5	14.2	21.9	29.7	35.6	42.2	49.0	55.6	61.1
Position change m1-m2	-0.5	-0.4	-0.3	-0.2	-0.1	-0.04	0.1	0.2	0.5
Position change m2-m3	-0.6	-0.5	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.5
Position change m3-finish	-0.9	-0.7	-0.4	-0.2	-0.04	0.13	0.4	0.7	1,3
VMG									
VMG leg1 (kts)	1.75	1.71	1.66	1.62	1.59	1.55	1.52	1.48	1.43
VMG leg2 (kts)	4.06	4.01	3.98	3.96	3.93	3.91	3.88	3.85	3.75
VMG leg3 (kts)	4.42	4.28	4.17	4.06	3.98	3.96	3.92	3.89	3.85
VMG leg4 (kts)	2.13	2.04	1.97	1.89	1.68	1.62	1.58	1.56	1.53
VMGdiff leg1 (kts)	0.07	0.12	0.19	0.23	0.25	0.28	0.30	0.16	0.33
VMGdiff leg2 (kts)	0.07	0.09	0.13	0.14	0.15	0.17	0.19	0.11	0.21
VMGdiff leg3 (kts)	0.05	0.09	0.13	0.14	0.15	0.16	0.18	0.12	0.19
VMGdiff leg4 (kts)	0.07	0.09	0.14	0.16	0.18	0.20	0.23	0.13	0.28
TIME									
Time leg1 (min)	18.4	19.1	19.5	20.0	20.4	20.7	21.1	21.4	21.9
Time leg2 (min)	7.0	7.0	7.0	7.0	7.2	7.6	7.7	7.8	7.9
Time leg3 (min)	6.8	7.0	6.9	7.0	7.2	7.9	8.0	8.1	8.2
Time leg4 (min)	15.3	15.6	15.8	16.0	16.3	16.6	17.0	17.2	17.9
Race time (min)	48.3	49.4	50.1	51.0	51.5	52.0	52.3	53.1	55.3
Time difference m1 (sec)	53.5	87.0	114.5	140.7	159.5	185.0	219.2	241.8	274.0
Time difference m2 (sec)	56.3	95.6	124.8	155.3	172.6	200.1	231.3	248.3	278.6
Time difference m3 (sec)	77.3	111.9	143.0	173.3	193.7	223.6	248.0	268.3	297.4
Time difference finish (sec)	100.6	159.4	206.3	249.1	272.3	315.9	351.8	389.3	437.2
DISTANCE									
Distance leg1 (m)	1488.5	1529.0	1558.4	1588.4	1604.3	1637.3	1663.0	1706.4	1763.4
Distance leg2 (m)	903.0	914.6	921.3	927.8	932.3	936.2	941.3	948.0	960.4
Distance leg3 (m)	860.6	866.3	873.2	879.8	884.7	890.0	896.2	907.0	924.0
Distance leg4 (m)	1286.4	1306.2	1318.7	1329.7	1341.7	1351.2	1365.2	1379.9	1462.0
Total race distance (m)	4607.9	4652.1	4689.7	4730.7	4753.6	4791.2	4838.9	4907.4	5038.3

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; VMGdiff: VMG difference from race winner; kts: knots; min: minutes; sec: seconds; m: metres

Table 3.5. Performance profile for final series (gold fleet) during IODA Optimist World Championships from 2014 - 2018 (n = 17 races).

GOLD FLEET	90%	80%	70%	60%	50%	40%	30%	20%	10%
POSITION									
Position m1	10.4	16.4	21.7	28.5	38.1	41.7	47.9	53.9	60.0
Position m2	9.9	15.8	21.1	27.7	37.3	41.3	47.0	53.9	60.0
Position m3	9.3	16.0	20.4	27.9	36.1	40.6	47.0	53.9	59.7
Position change m1-m2	-1.1	-0.6	-0.5	-0.3	-0.3	-0.2	0.1	0.3	0.9
Position change m2-m3	-1.3	-0.9	-0.6	-0.5	-0.4	-0.1	0.0	0.4	0.9
Position change m3-finish	-1.5	-0.6	-0.4	-0.2	0.0	0.2	0.8	1.1	1.8
VMG									
VMG leg1 (kts)	1.84	1.82	1.78	1.74	1.70	1.67	1.60	1.58	1.53
VMG leg2 (kts)	4.26	4.20	4.16	4.14	4.11	4.03	3.97	3.86	3.74
VMG leg3 (kts)	4.13	4.06	4.01	3.98	3.93	3.88	3.79	3.73	3.62
VMG leg4 (kts)	1.86	1.83	1.80	1.77	1.74	1.71	1.67	1.64	1.59
VMGdiff leg1 (kts)	0.12	0.17	0.22	0.24	0.30	0.35	0.42	0.47	0.52
VMGdiff leg2 (kts)	0.02	0.08	0.11	0.13	0.15	0.16	0.18	0.20	0.25
VMGdiff leg3 (kts)	0.03	0.07	0.09	0.12	0.13	0.15	0.17	0.20	0.27
VMGdiff leg4 (kts)	0.05	0.09	0.11	0.13	0.14	0.16	0.17	0.19	0.22
TIME									
Time leg1 (min)	16.4	16.9	17.0	17.3	17.7	18.2	18.5	18.8	19.2
Time leg2 (min)	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.4	7.6
Time leg3 (min)	7.3	7.6	7.6	7.7	7.7	7.8	7.8	8.0	8.1
Time leg4 (min)	14.3	14.4	14.7	14.8	15.0	15.2	15.6	15.8	16.2
Race time (min)	45.3	46.1	46.5	47.1	48.0	48.6	48.9	49.3	50.5
Time difference m1 (sec)	56.8	78.6	98.5	120.7	136.1	159.4	178.4	200.8	227.2
Time difference m2 (sec)	63.9	86.8	104.8	130.8	149.8	171.4	180.3	203.3	230.3
Time difference m3 (sec)	80.1	102.8	123.1	157.2	171.4	189.1	200.4	225.4	245.1
Time difference finish (sec)	111.4	148.6	177.2	211.5	246.8	267.2	287.5	311.2	362.5
DISTANCE									
Distance leg1 (m)	1452.2	1476.4	1498.3	1517.0	1555.0	1570.2	1603.0	1627.5	1655.4
Distance leg2 (m)	890.1	909.3	920.9	928.8	933.1	940.1	945.3	960.5	973.2
Distance leg3 (m)	908.3	941.4	947.1	961.8	971.0	981.7	991.4	1011.6	1024.1
Distance leg4 (m)	1240.0	1262.1	1275.6	1292.7	1306.9	1323.4	1340.5	1374.2	1391.8
Total race distance (m)	4537.1	4615.9	4646.4	4716.9	4739.7	4803.7	4892.6	4943.2	4979.0

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; VMGdiff: VMG difference from race winner; kts: knots; min: minutes; sec: seconds; m: metres

Table 3.6. Performance profile for final series (silver fleet) during IODA Optimist World Championships from 2014 - 2018 (n = 17 races).

SILVER FLEET	90%	80%	70%	60%	50%	40%	30%	20%	10%
POSITION									
Position m1	9.3	14.2	22.6	29.9	34.5	41.9	48.6	55.3	59.5
Position m2	9.0	14.1	22.3	29.0	34.7	42.1	48.9	55.3	59.0
Position m3	8.4	14.7	21.0	26.4	34.1	41.5	49.4	55.8	59.0
Position change m1-m2	-2.1	-1.0	-0.7	-0.3	0.0	0.5	1.0	1.0	1.5
Position change m2-m3	-3.7	-2.5	-1.5	-0.5	-0.1	0.0	1.3	1.9	2.6
Position change m3-finish	-3.0	-2.0	-1.5	-0.8	0.0	1.0	1.2	2.0	4.4
VMG									
VMG leg1 (kts)	1.88	1.82	1.75	1.73	1.70	1.67	1.65	1.60	1.55
VMG leg2 (kts)	5.45	5.03	4.93	4.81	4.63	4.30	4.11	4.05	4.00
VMG leg3 (kts)	5.15	4.87	4.80	4.63	4.45	4.39	4.30	4.25	4.10
VMG leg4 (kts)	1.90	1.85	1.80	1.73	1.70	1.65	1.60	1.60	1.50
VMGdiff leg1 (kts)	0.08	0.10	0.15	0.20	0.20	0.25	0.27	0.30	0.35
VMGdiff leg2 (kts)	0.00	0.10	0.10	0.16	0.21	0.25	0.36	0.60	0.98
VMGdiff leg3 (kts)	-0.13	-0.03	0.03	0.05	0.10	0.15	0.20	0.30	0.44
VMGdiff leg4 (kts)	0.03	0.05	0.10	0.10	0.15	0.18	0.20	0.23	0.30
TIME									
Time leg1 (min)	18.7	19.3	19.9	20.4	20.7	21.0	21.4	21.8	22.3
Time leg2 (min)	5.2	5.5	5.7	5.8	6.0	6.1	6.1	6.2	6.5
Time leg3 (min)	6.4	6.6	6.9	7.0	7.2	7.5	7.5	7.6	7.9
Time leg4 (min)	12.7	13.0	13.2	13.4	13.7	13.9	14.1	14.5	15.3
Race time (min)	44.7	46.2	46.6	47.2	47.6	48.1	48.6	48.8	50.0
Time difference m1 (sec)	52.6	70.1	95.3	115.1	138.1	158.3	170.5	191.6	241.6
Time difference m2 (sec)	60.1	79.0	105.0	125.1	147.5	171.6	186.5	222.1	260.8
Time difference m3 (sec)	74.7	97.6	115.8	141.6	167.9	178.6	198.8	221.2	266.2
Time difference finish (sec)	98.9	127.6	157.4	197.3	232.7	262.3	289.8	321.2	434.0
DISTANCE									
Distance leg1 (m)	1770.3	1827.4	1856.8	1874.7	1897.5	1931.7	1956.3	1982.4	2056.2
Distance leg2 (m)	834.8	898.8	904.1	941.0	951.5	963.5	981.7	1005.0	1028.9
Distance leg3 (m)	965.2	1051.2	1071.2	1097.2	1104.8	1110.5	1121.7	1161.4	1231.1
Distance leg4 (m)	1138.8	1159.4	1191.7	1221.8	1248.2	1268.9	1310.9	1340.5	1418.9
Total race distance (m)	4984.7	5032.2	5079.7	5152.1	5184.5	5269.1	5294.6	5369.3	5515.7

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; VMGdiff: VMG difference from race winner; kts: knots; min: minutes; sec: seconds; m: metres

Table 3.7. Performance profile for final series (bronze fleet) during IODA Optimist World Championships from 2014 - 2018 (n = 15 races).

BRONZE FLEET	90%	80%	70%	60%	50%	40%	30%	20%	10%
POSITION									
Position m1	9.0	15.0	21.0	27.0	35.8	42.5	47.5	51.0	59.6
Position m2	9.1	14.0	20.1	27.5	36.0	40.5	47.3	51.8	59.7
Position m3	8.6	13.5	19.4	28.0	34.8	41.7	46.4	53.0	59.1
Position change m1-m2	-2.3	-1.0	-1.0	-0.5	0.0	0.0	0.6	1.0	1.5
Position change m2-m3	-3.1	-2.0	-1.4	-1.0	-0.6	-0.3	0.5	1.5	2.0
Position change m3-finish	-2.5	-2.0	-1.3	-1.0	-0.1	0.5	1.6	2.5	4.0
VMG									
VMG leg1 (kts)	1.90	1.87	1.83	1.80	1.75	1.70	1.67	1.65	1.60
VMG leg2 (kts)	5.26	4.95	4.85	4.63	4.31	4.17	4.04	3.95	3.83
VMG leg3 (kts)	5.16	5.00	4.83	4.47	4.28	4.20	4.13	4.05	3.86
VMG leg4 (kts)	1.80	1.74	1.66	1.62	1.55	1.50	1.50	1.50	1.40
VMGdiff leg1 (kts)	0.09	0.13	0.15	0.20	0.23	0.27	0.30	0.35	0.43
VMGdiff leg2 (kts)	-0.10	0.00	0.04	0.10	0.11	0.18	0.24	0.45	0.90
VMGdiff leg3 (kts)	-0.32	-0.15	-0.04	0.00	0.13	0.20	0.38	0.60	1.03
VMGdiff leg4 (kts)	0.06	0.10	0.17	0.20	0.20	0.23	0.29	0.33	0.40
TIME									
Time leg1 (min)	18.3	18.7	18.9	19.5	19.8	20.7	21.2	21.7	22.5
Time leg2 (min)	5.4	5.7	5.8	6.0	6.2	6.3	6.4	6.7	7.3
Time leg3 (min)	6.3	6.5	6.8	7.1	7.4	7.7	7.9	8.3	9.0
Time leg4 (min)	13.7	14.1	14.3	14.4	14.7	15.0	15.6	16.0	17.0
Race time (min)	44.9	45.9	46.3	47.5	48.0	49.8	50.6	51.4	53.1
Time difference m1 (sec)	44.3	76.8	93.5	114.3	136.2	159.0	194.8	212.0	301.1
Time difference m2 (sec)	46.3	82.0	98.3	119.0	140.3	171.5	199.5	241.3	340.7
Time difference m3 (sec)	57.8	102.5	118.5	131.8	152.2	187.0	209.9	302.3	431.2
Time difference finish (sec)	94.4	136.0	171.0	188.8	248.0	290.7	335.8	408.0	609.8
DISTANCE									
Distance leg1 (m)	1737.5	1755.5	1811.4	1835.0	1859.0	1910.3	1962.7	2013.5	2101.0
Distance leg2 (m)	868.5	896.5	901.6	932.0	946.3	964.5	1001.1	1020.8	1042.8
Distance leg3 (m)	913.3	1009.5	1072.7	1087.5	1112.4	1122.0	1156.7	1197.3	1300.5
Distance leg4 (m)	1220.6	1247.0	1283.8	1303.0	1337.0	1381.5	1435.0	1524.5	1626.7
Total race distance (m)	4937.5	5073.3	5134.0	5193.0	5252.3	5383.5	5473.0	5583.7	5805.3

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; VMGdiff: VMG difference from race winner; kts: knots; min: minutes; sec: seconds; m: metres

Table 3.8. Performance profile for final series (emerald fleet) during IODA Optimist World Championships from 2014 - 2018 (n = 11 races).

EMERALD FLEET	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**
POSITION									
Position m1	9.3	15.4	20.9	26.8	32.5	39.9	46.8	53.2	58.1
Position m2	9.2	15.1	21.1	27.2	32.4	40.1	47.1	53.4	58.0
Position m3	8.5	13.7	20.9	26.8	33.1	39.6	46.7	52.0	57.7
Position change m1-m2	-1.0	-0.8	-0.5	0.0	0.0	0.3	0.5	0.7	1.0
Position change m2-m3	-2.1	-1.2	-0.8	-0.5	-0.3	-0.1	0.1	0.3	0.7
Position change m3-finish	-1.4	-0.8	-0.6	-0.4	0.3	0.6	1.2	1.7	2.5
VMG									
VMG leg1 (kts)	1.71	1.68	1.64	1.59	1.54	1.61	1.50	1.45	1.40
VMG leg2 (kts)	4.07	3.98	3.93	3.87	3.84	3.89	3.82	3.77	3.72
VMG leg3 (kts)	3.89	3.80	3.76	3.69	3.64	3.73	3.56	3.52	3.42
VMG leg4 (kts)	1.69	1.65	1.63	1.61	1.58	1.62	1.54	1.50	1.45
VMGdiff leg1 (kts)	0.06	0.10	0.13	0.21	0.15	0.19	0.25	0.28	0.30
VMGdiff leg2 (kts)	0.00	0.02	0.03	0.06	0.04	0.05	0.08	0.09	0.11
VMGdiff leg3 (kts)	0.04	0.06	0.09	0.13	0.10	0.10	0.14	0.18	0.24
VMGdiff leg4 (kts)	0.00	0.04	0.05	0.10	0.06	0.09	0.12	0.13	0.15
TIME									
Time leg1 (min)	17.6	17.9	18.5	18.9	19.4	19.7	20.2	20.9	21.6
Time leg2 (min)	6.8	6.8	6.9	7.0	7.1	7.1	7.2	7.2	7.3
Time leg3 (min)	7.8	7.9	7.9	8.1	8.1	8.2	8.3	8.4	8.5
Time leg4 (min)	15.3	15.5	15.7	15.8	16.0	16.2	16.5	16.6	17.0
Race time (min)	48.1	48.9	49.7	50.5	51.0	51.4	51.8	52.3	52.6
Time difference m1 (sec)	48.4	79.8	95.2	118.7	138.0	157.6	179.9	207.4	239.3
Time difference m2 (sec)	52.2	80.1	106.7	130.8	147.3	168.2	185.5	214.6	246.6
Time difference m3 (sec)	65.8	94.0	121.3	146.0	171.2	188.0	219.5	239.7	278.9
Time difference finish (sec)	74.6	124.1	158.9	205.8	234.1	247.9	272.4	294.7	337.3
DISTANCE									
Distance leg1 (m)	1490.9	1528.0	1546.4	1574.7	1596.1	1625.8	1662.2	1705.3	1779.0
Distance leg2 (m)	869.2	877.8	891.8	895.2	907.5	913.3	918.2	932.7	961.7
Distance leg3 (m)	925.3	955.4	973.8	985.2	1012.9	1023.1	1043.4	1069.3	1113.6
Distance leg4 (m)	1279.0	1292.8	1301.1	1315.0	1342.8	1366.9	1399.1	1439.4	1488.9
Total race distance (m)	4653.5	4687.9	4740.7	4769.8	4853.6	4953.1	5019.0	5094.4	5239.5

m1: mark 1; m2: mark 2; m3: mark3; VMG: velocity made good; VMGdiff: VMG difference from race winner; kts: knots; min: minutes; sec: seconds; m: metres

3.4 Discussion

In the present study, GPS units were used to track the sailors and subsequently gain information about the sailor's performance during high-level Optimist sailing races. The data was used to determine a race performance profile of these races. No previous study to date has incorporated the techniques used in the present study to investigate and compare the positions, speeds, distances and times Optimist sailors attain during competition. This is, therefore, the first study to investigate race PIs in Optimist sailing races and develop a performance profile which coaches and sailors can use to analyse their performance.

In 2008, O'Donoghue and colleagues [2] suggested that performance profiles should be established in the context of coaching, as opposed to academic research only. Therefore, the present study aimed to identify appropriate and useful PIs using a combined approach i.e. coaches input and statistical analysis. A reasonable relationship between the variables identified by the coaches and those the analytics determined as being significant was expected.

Interestingly, the variable most often identified through statistical analysis as being the best predictor (i.e. time taken in each leg) was not necessarily something most sailing coaches would find useful when analysing the race performance of their sailor. For instance, while it seems obvious that a shorter time will indicate better performance, coaches are less concerned with the time taken to sail around the course and more concerned about the sailor's current position within the fleet.

Due to the structure of the race, the nearly perfect relationships between position at each mark and final race outcome is also not unexpected. What was noteworthy was that in all races of the qualifying series and the gold fleet (final series) minimal changes in position occurred. Irrespective of the percentile band, sailors only lost or gained an average of one position (Table 3.5). The emerald fleet shows more position changes in the lower-skilled sailors; who lose most positions in the final leg (Table 3.7). While the most substantial changes in performance were between the sailors in the silver and bronze fleets, particularly in the final leg (Table 3.6 and 3.8). Thus, once a sailor in the qualifying series and gold fleet has raced the first leg to the top mark, the positions are unlikely to change too dramatically for the rest of the race. This information highlights the importance of the first upwind leg as being a critical point during the race, as it relates most strongly with the outcome. It may also suggest that the sailors in the gold fleet are more similarly match compared to the other fleets in the final series. In that, while the fleet is condensed (the whole fleet crosses the finish line within about five minutes from one another), all the sailors are performing consistently within the race.

Therefore, it becomes more difficult to overtake and gain positions at any point during the race. In contrast, the bronze fleet indicates the most inconsistent performances, in that the top and bottom sailors varied the most in the distance sailed, the time difference from the leader and positional changes (gain or loss) within each leg. This may indicate that the bronze fleet includes sailors with the most significant skill level gap.

Consequently, the time difference from current race leader may be more applicable for coaches. The time difference from leader indicates how, in all series and fleets, the leaders consistently gain time on the sailors in the bottom group of the race. This may link back to the point made earlier regarding the clear lane or clean air. The boats in the front of the race are less concerned with going in search of clear air since there are fewer boats in their vicinity which can affect the wind immediately around them. Therefore, they can spend more time analysing and ‘reading' the environmental conditions (i.e. wind direction, speed and wave action).

Furthermore, if a sailor wishes to be in the top position in the gold fleet, they should aim to be within 122 to 124 seconds of the race leader at marks 2 and the finish, respectively. The difference here may be that the It is essential to highlight that while the sport is not based on time; the variable was included as a PI as it provides descriptive information on high-level Optimist races. Additionally, this information may be useful for coaches during their planning and implementation of certain training interventions.

On the other hand, the velocity made good (VMG) difference from the overall race winner was recommended as being the most useful by sailing coaches. The VMG determines how fast a sailor is sailing towards their destination, in this case, the next mark. In order to have a chance of getting ahead of the other competitors, a sailor’s objective is to get from mark to mark in the shortest possible distance at the fastest possible speed. A higher VMG score indicates a better value; thus, the challenge for any sailor is to maintain as high a VMG as often as possible. The combination of the VMG results and the longer distances sailed in all races (irrespective of series or fleets) may indicate a possible strategy of those sailors towards the back of the fleet. In that they may decide or are forced to sail further distance in search of a lane or clear air, or on the other hand, their VMG is worse since the wind ahead of them is impacted by the other boats, thus their angle to the wind (see Figure 2.1) and corresponding speed is affected. However, the information relating specifically to VMG and the difference between sailors may become more useful and the feedback more effective when the sailor has reached a level of performance which requires minimal attention to boat-related manoeuvres. Therefore, the sailor can better attend to environmental cues and try to position their boat on the course and in relation to the other boats to take advantage of an expected wind shift or gust.

O'Donoghue and colleagues [2] emphasise the need to consider the quality of the opposition when determining and evaluating athletic performance; as this is the greatest source of variability. We agree that the relative quality (opposition quality) of the competition is an important factor to consider, however, in the current study this was not achievable using the method suggested by O'Donoghue and Cullinane [20]. Firstly, this profiling method makes use of ranking systems, which determines better or worse performances and more or less skilled athletes. Unlike in other sailing classes, Optimist sailors do not have a world ranking which can be used to determine their quality as a competitive sailor. Secondly, the sports who have implemented this profiling approach are one-on-one sports like tennis [7,20]. Optimist sailing is a mass start event with several opponents of varying skill levels. As a result, we were unable to address, based on the O'Donoghues method [2], the performance differences taking opposition quality into account. However, we did attempt to consider the quality of the opponents by establishing performance profiles of each fleet once the competitors were split after the qualifying series. Since, when split into the respective fleets, the sailors race the remainder of the regatta against more similarly matched or skilled sailors.

A sailor's performance throughout a 50-minute race may not always be similar in quality; for example, in leg 1 the sailor may have performed above the 50th percentile, but the following three legs were below the 50th percentile, thus affecting their finishing position. Having this knowledge is helpful to coaches since it can enable a more thorough understanding of an Optimist sailor's performance in different areas of a race, such as where they gained or lost the most amount of time and if this corresponded to a gain or loss in overall rank. Therefore, while the PIs and performance profiles identified and established in this study are valuable; coaches must provide feedback to their sailor, which will help them to improve their performance. For this to happen, it is essential that the coach knows their athlete and can determine how much and how specific the information given ought to be [3], accounting for their skill level and experience. As such, the information presented in this study may not be appropriate for sailors who are still mastering the fundamentals of boat handling and awareness of the various environmental conditions. A coach must provide feedback which will facilitate improved performance rather than hindering it, i.e. to provide enough but not too much information for the sailor to focus on. If, for example, the feedback is overly complicated and the coach provides too much information, the sailor may go away confused and discouraged. Future studies should consider how and when sailing coaches provide feedback and the possible impact the timing of the feedback may have on their sailor's performance.

This study proposes the use of objective PIs for feedback on race performance. However, the authors suggest that the information should not be used as a single measure of performance.

The process of race analysis and feedback to the sailors has many practical difficulties. Organisational rules at the IODA OWC state that the coach and supporter boats must remain in a waiting area zone, behind the start line, until the last fleet of the race has started. After that, they are required to remain well clear of the fleet by staying outside the exclusion boundary, which is approximately 100 metres from the racecourse [21]. Since it takes between 30 and 40 minutes to start all four fleets at the IODA OWC, the coaches generally anchor their boats in the waiting area and stay there for the duration of the racing. Thus, the coaches have a minimal view of the racing and are only able to discuss the race with their sailors when they return to the starting area. Since the implementation of GPS trackers on the boats, the coaches are better able to follow the racing (i.e. on tablets which they carry with them on the water) and compare the performance of their sailor to the other competitors. The analysis performed on the GPS data will help Optimist sailing coaches to have a practical impact on developing performance and ensuring the sailors are competing at their level. Furthermore, there is an opportunity to provide coaches with more accurate information. There is also a possibility that coaches may use this information as post-regatta analysis and subsequently, determine the areas within a race which require the most immediate attention and focus on these during training.

Athletic performance is not always consistent; in some cases, the quality of the performance is diminished, or an athlete may have a weakness in a specific area. In a sailing race for example, a sailor may misread environmental cues, not have the physical endurance to control the boat in specific wind intensities, or they may make tactical errors at critical points during the race. Therefore, this research provides information on the pattern of performance during elite level Optimist sailing races, through objective values at various critical points in the race. This is useful for coaches in that it adds to the tools available for performance analysis of their sailors in various aspects of the race with respect to the other sailors competing.

Limitations

A limitation of this study is that the information used to determine the performance profile is limited to the data provided online. While it is practical to use the positions at the various stages of the race, the limitation is that without subjective or additional data, a coach will not be able to determine the reason for a poorer result or position. Additionally, the performance profiles do not take into account the sailing experience and relative skill level of the Optimist sailors. However, it is assumed that this information is useful to all sailors competing in an

OWC regatta. Secondly, the specifics within each leg, such as course sailed, and a number of manoeuvres were not taken into account. This may provide more insight into the race pattern, and a possible connection between the manoeuvres and PIs identified in the present study. Finally, unlike the final series races, the competitors during the qualifying series were not able to be compared in terms of the opposition quality.

3.5 Conclusion

The benefit of having this information available to coaches and sports scientists is that they are able to give more specific feedback to their sailor based on the objective variables within a race, as well as at specific key points in the race, like mark rounding's. While this data is useful for coaches, it is important that the feedback provided is a combination of these objective PIs and some breakdown of the contextual factors and environmental consideration.

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CHAPTER 4: ARTICLE TWO

Competition and Training Load of High-level Competitive Non-motorised Surface Water Sports Athletes: A Scoping Review of Athlete Monitoring Methodology

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Abstract

Monitoring athletes during training and competition are necessary to gain information relating to the fitness and fatigue of the athlete in order to prescribe training load more precisely. The ultimate goal of this process is to improve performance and reduce the risk of injury. This scoping review aimed to appraise the existing research on internal and external load monitoring of high-level athletes in non-motorised surface water sports; thereby identify the most commonly used method in these competitive sport types and guide future research. The Joanna Briggs Institute' scoping methodological frameworks served as the guide to provide clarity and rigour in the review. Studies included in this review were published before August 2019 and were identified through a systematic search of the databases: Academic Search Premier; Google Scholar, SPORTDiscus and SpringerLink. The literature search presented 20 of 6567 papers deemed relevant to the aim of the review. The findings revealed that HR-based methods are most commonly used when monitoring internal load; while duration, followed by distance, is used most often for external load monitoring of athletes in non-motorised surface water sports. The findings highlight the need to increase athlete monitoring specifically regarding youth and females, and in specific sports such as sailing. Thus, future research should aim to develop ecologically valid monitoring methods in sailing.

Keywords: *athlete monitoring, training load, competition load, non-motorised surface water sport*

Authors

CW and KW drafted the manuscript. ML acted as the third reviewer in case of disagreement between two primary reviewers. CW contributed to the conception and design of the review, prepared the first draft and developed the search strategy. All authors read, provided feedback and approved the final manuscript.

4.1 Background

Identifying the demands of competition and training is essential for the designing of appropriate training programs that will maximise an athlete's performance in a competition [1-3]. Numerous investigations have highlighted the need for athlete monitoring and the development of appropriate monitoring processes to aid an athlete in training for improved performance [3,4-12]. Athlete monitoring refers to the methods by which sports scientists and practitioners investigate the competition (CL) and training load (TL), i.e. stressors or demands an athlete is exposed to during competition and training and in some cases the corresponding response to the training [2, 13-15]. Accordingly, load is fundamentally the product of an activity's duration and intensity.

Tracking TLs are vital as recent research supports a positive relationship between athletes' TL and injury rates [7, 16]. Consequently, as increasing demand is placed on high-level competitive athletes, continual monitoring of individual responses to training stimuli has become crucial in the training setup. Consequently, when an athlete reaches the fatigue threshold, it will deplete their reserve capacities and lead to a failure to adapt. In return, this may result in disproportionately accumulated fatigue and may lead to overtraining [17]. Thus, athlete monitoring methods need to determine an athlete's tolerance or stress to the training stimulus and whether they should maintain, increase or decrease their current TL. The rationale for this practice is based on Selye's General Adaptation Syndrome, which states that an athlete will adapt to any stressors they might experience in an attempt to meet the demands of these stressors [18]. Whereas, CL gives insight into the physical and physiological demands of sports competition, which is critical to determine if training is adequate for the specific requirements of the competition [2].

Athlete monitoring methods can be divided into i) tracking (e.g. global positioning systems (GPS)), ii) self-report (e.g. ratings of perceived exertion (RPE)) or iii) performance testing (e.g. submaximal or maximal tests). However, often, athlete monitoring takes place in the form of indirect measures of maximal performance or relevant sport-specific characteristics. Furthermore, research on load monitoring is typically divided into two categories; either i) external load (e.g. time, training frequency, distance, video-based time-motion analysis (TMA), power output, speed, acceleration and neuromuscular performance tests); or ii) internal load (e.g. RPE, heart rate (HR), blood lactate (La), oxygen uptake, wellness questionnaires, and biochemical, hormonal and immunological responses) [11]. According to Wallace and colleagues [19], external load is the work done by the athlete independent of their internal characteristics or strain. In contrast, internal load is more about the body's response to the external load (i.e. relative physiological and psychological stress inflicted on the athlete) [11].

Therefore, external load provides an understanding of the work completed as well as capabilities of the athlete, while internal load is often used for determining fitness outcomes by shaping the TL and subsequent adaptation. In addition, the ratio between external and internal load has also been used to assess the state of fatigue of an athlete [11].

For the purpose of this review, non-motorised (namely environmentally and self-propelled) surface water sports are defined as a sport involving the control and propulsion of an object (e.g. a boat or board) over the surface of the water, using either environmental factors (like wind and/or waves) or self-propelled methods (i.e. paddling). Examples of sports include kayaking, kiteboarding/surfing, rowing, sailing, stand up paddling, and surfing. Comprehensive knowledge of existing trends and monitoring techniques used during non-motorised surface water sports is crucial for a better understanding of the loads that these athletes are exposed to during both training and competition. Particularly since these sports have an added variable, to contend with and overcome, namely the 'playing' surface. Specifically, to perform optimally, the 'playing' surface, which is continuously moving (i.e. with currents or waves) or merely the changeable quality of water (i.e. fluidity) needs to be conquered.

While athlete monitoring has been well established and is utilized in a range of sporting codes [20], from team [1,3,13,21-23] to individual sports [24-26], it has not been used extensively in surface water sports. The reason for this maybe since the monitoring measures used in land-based sports were initially not deemed feasible for water-based sports. However, this is changing as these sport types are becoming more popular, professional and competitive. Nevertheless, due to the competing athlete's dependence on environmental conditions as well as the actions of the competitors, the competition results in these sports are inherently difficult to analyse [27]. Consequently, water-based monitoring is often faced with logistical challenges because the technical equipment used in land-based sports has not yet been made waterproof and/or wireless. Furthermore, some of these sports, such as sailing and rowing, take place over vast distances making it difficult to track/video during the entire event.

Two reviews, to date, have focused explicitly on TL and CL monitoring in non-motorised surface water sports. Farley and colleagues [28] explored the use of video-based TMA, GPS devices and HR indices during a surfing competition. Mäestu and colleagues [27] considered performance and training monitoring in rowing, with a specific focus on preparation leading up to a competition. The researchers also suggest that the few studies which have investigated monitoring in rowing have not determined a single marker of training monitoring. While another review by Shepard [29] did include a brief section on monitoring training of rowers, but the specific focus of this review was actually on rowing injuries. Whereas the review by Smith and

Hopkins [30], studied the measures of rowing performances and the associated performance testing available for rowers. With this in mind, researchers must start looking at feasible monitoring measures that are specific to surface water sports and not based on other water sports such as swimming. Accordingly, given that surface water sports are largely under-represented in the literature of athlete monitoring, the purpose of this scoping review is to investigate the existing research surrounding the CL and TL methodologies implemented by coaches, sports scientist and researchers, as well as identify gaps in the knowledge base of monitoring load in non-motorised surface water sports specifically for high-level competitive athletes (including national and international level athletes).

Therefore, the aims of this scoping review were to i) identify and characterize the main methodologies used to monitor competition and training loads (i.e. external and internal) in high-level competitive non-motorised surface water sports athletes with the goal of determining which monitoring method is the most commonly used to measure athletic performance, and ii) to provide future directions for research on athlete monitoring in these sports.

4.2 Methods

Study Selection: Inclusion and Exclusion Criteria

All observational studies considered for this review were published before August 2019 in English and available in full text, peer-reviewed in scientific journals (see Table 4.1 for complete in- and exclusion criteria).

Participants in the respective studies were limited to high-level competitive athletes who were predefined as *an individual who participates in an organized team or individual sport that requires regular competition (at elite or national and international level) against others as a central component, places a high premium on excellence and achievement, and requires some form of intense systematic training* (adapted from the 36th Bethesda conference [31]). The reason we chose high-level competitive athletes as the study population was to ensure that the participants in the studies performed at similar competitive events.

Table 4.1. Scoping review specific in- and exclusion criteria for publications.

Inclusion criteria	Exclusion criteria
• Surface water sports[1] [i.e. canoeing, canoe polo, kayaking, kiteboarding, rowing, sailing, stand up paddling, surfing and windsurfing]. • Any age and sex. • Any form of athlete monitoring [i.e. self-report, tracking or performance testing] during a training session and/or formal competitive event. • Monitoring measures [i.e. internal TL - HR, HR recovery, RPE, session RPE, neuromuscular function, biochemical/ hormonal/ immunological assessments, questionnaires (e.g. REST-Q), sleep quantity & quality; external TL - GPS, video-based TMA, session duration & frequency, repeat efforts, speed, accelerations, power output, training type, distance]. • 80% of the sample must be surface water sport[1], high-level competitive, athletes. • peer-reviewed observational studies (including both descriptive & analytical designs).	• Only provided a technical description of the movements in the sport. • Review articles, case studies[2], epidemiological studies and interventions. • Not full-length papers or grey literature (such as conference proceedings) and non-peer-reviewed papers (like dissertations and theses). • non-competitive or leisure sports, i.e. recreational, amateur and club level athletes

[1]:Non-motorised i.e. environmentally & self-powered; [2]:Case study research may feature single cases or multiple cases (e.g., often two to three) [32]; TL: Training load; HR: Heart rate; RPE: Ratings of perceived exertion; REST-Q: Recovery-Stress Questionnaire; GPS: global positioning systems; TMA: time-motion analysis.

Publications included were required to describe the methodology used to monitor the athletes during training and/or competition of non-motorised surface water sports. Using these conditions, 20 articles met the inclusion criteria and were identified as relevant to the current review.

Data Sources and Search Strategies

An electronic literature search of four electronic databases (Academic Search Premier; GoogleScholar, SPORTDiscus™ and SpringerLink) was conducted. Search terms (see Table 4.2) were connected with ‘OR’ within each of the two combination groups and these were combined using ‘AND’; for example: *monitoring methods AND training load AND sail* OR surf**. The sport terms were truncated using the asterisk (*) symbol and the final search was conducted on 1 September 2019. The process used for selecting the articles used in this review is outlined in Figure 4.1.

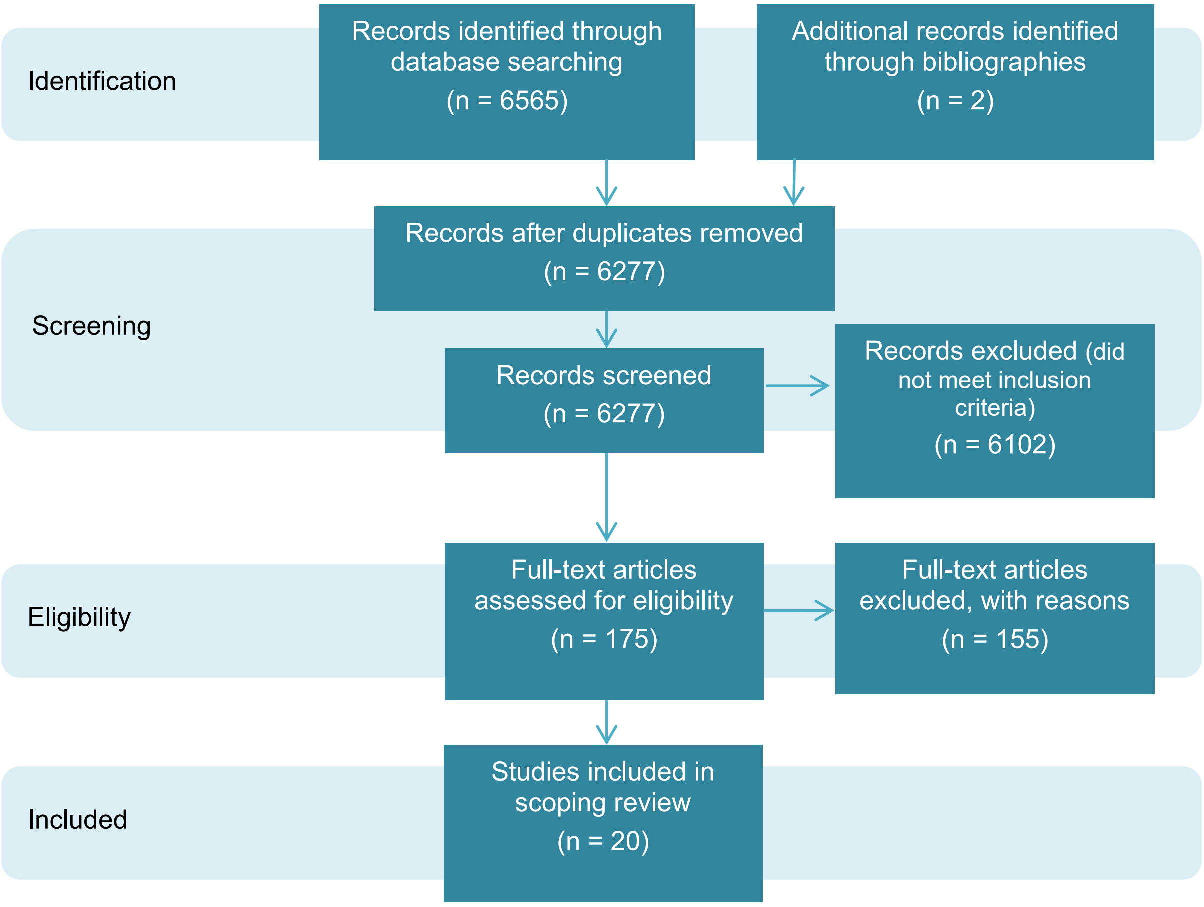

Figure 4.1. Schematic overview of the selection process for the inclusion of articles in the scoping review [33].

Initially, the titles and abstracts of the publications were screened independently by the reviewers (CW and KW) to decide whether the inclusion criteria were met. A full-text article review followed this. In case of disagreement between two primary reviews (CW & KW), a third reviewer (ML) was asked to review the publications in question. Reference lists of included articles were scanned to identify possible articles which may have been missed in the original search.

Table 4.2. Database search strategy.

Athlete monitoring	athlete monitoring OR monitoring methods
Training load	training load OR internal load OR subjective OR external load OR objective OR activity profile
Surface water sports	surface water sport OR canoe* OR kayak* OR kiteboarding OR paddle* OR row* OR sail* OR stand up paddle* OR SUP OR surf* OR windsurf*

* the terms were truncated

Data Extraction

The first author (CW) extracted data from all included studies. Data relating to the athlete characteristics (sex, age, level of competition, training phase), length of the monitoring period, phase of training, and monitoring method used (self-reported, tracking, performance testing), and all monitoring outcome variables were collected by two authors (CW, KW).

Risk of Bias Assessment

An assessment of the methodological strength and risk of bias for the eligible studies was determined using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies scale [34], which ranges from 0 to 14 points. A score of over 80% was considered 'good', 60-80% 'fair', and under 60% was considered poor; In general, a "good" study has the least risk of bias, and results are considered to be valid. The broad 'fair' category is susceptible to some bias deemed not sufficient to invalidate its results, but studies with this rating will vary in their strengths and weaknesses. While a "poor" rating indicates a significant risk of bias. Due to the limited studies, available studies rated poor were not excluded (Table 4.4). Scores were adjusted for descriptive [35] vs. analytical [36] observational studies. Specifically, if the question did not apply to a descriptive non-analytical study, then this question was given an "NA", and it did not count negatively towards the quality rating. The total agreement (Good/Fair/Poor) between assessors was high (23/27 = 85%).

4.3 Results

Main Findings

This search yielded 6567 potentially relevant articles. A total of 6277 abstracts and 175 full text articles were selected for review and, of these, 20 studies met the inclusion criteria (Figure 4.1).

Characteristics of the Studies

Most studies were considered correlational analytical observational studies in naturalistic settings. An overview of the articles included is provided in Table 4.3. The articles included from the respective sports: canoeing (n = 0), canoe polo (n = 1), kayaking (n = 3), kiteboarding (n = 1), rowing (n = 8), sailing (n = 0), stand up paddling (n = 1), surfing (n = 3) and windsurfing (n = 3). There has been a slow growth in the number of studies published on this topic, 65% of the studies included were published after 2010 and, of these, about half (54%) were published after 2015. While 35% were published between 1999 and 2009. Nine studies only focused on the CL, while four studies monitored a combination of TL and CL, one study only monitored the TL in the recovery phase, and the remaining six studies only observed TL over the preparatory and overload phases. For the TL studies the timeframe varied from a single session up to 42 weeks. The results also report on a 30-year retrospective study [24].

Characteristics of the Athletes

Even though almost half the studies (n = 10) included a mixture of both sexes, of the total 324 athletes, 87% were males. The remaining 13% of females that were included participated in kayaking (n = 3 studies), rowing (n = 5 studies) and one from stand-up paddling as well as windsurfing. No study looked at only female athletes. The ages of the included participants ranged from 17 to 34 years. Three studies did not provide a clear indication of the ages of their included athletes [24,38,39]. Only two studies [10,40], in kayaking, reported monitoring of youth athletes (≤18 years).

Monitoring Methods

The monitoring methods investigated were categorised as self-report, tracking and performance testing. Where tracking considers aspects of external load measured through GPS (such as distance and frequency of event) or video-based TMA (for example percentage time spent in sport mode, i.e. paddling in surfing) [41]. In this review, only two studies described TLs and CLs in all three monitoring methods, six studies described a combination of self-report and performance testing measures (TLs), and eight studies described a combination of tracking and performance testing measures (CLs) (see Table 4.3). Three studies described performance testing measures only (CLs), while one considered tracking only (CLs). Interestingly, 94% of the studies which reported CLs used some form of performance testing measure. The included studies also varied in that both internal and external TLs and CLs were reported by 16 of the studies (80%), while three (15%) reported only internal TLs and CLs and one (5%) on external CLs.

The most commonly reported measures of athlete monitoring for internal TLs and CLs (accounting for 44% of the measures reported) are HR indices (13%), followed by blood samples (9%), VO_2 (oxygen uptake) (7%) and RPE measures (5%). Whereas, for external TLs and CLs (49% of the reported monitoring methods) duration (15%) and specific GPS measures including distance (sometimes referred to as course sailed) (8%) and speed (7%) were most often reported. These were followed by power output (4%), strength testing (3%) and training volume (3%). Other measures included the use of energy expenditure, questionnaires, training impulse (TRIMP), ventilatory threshold, saliva samples, number of efforts, training types and reported wind intensities. Two studies looked into a novel method of determining TL in rowing specifically, identified as the T2minute method [42,43]. Based on these findings there appears to be evidence that HR indices and GPS measures (distance and speed) are most often used when monitoring TLs and CLs of athletes in non-motorised surface water sports compared to other methods.

It is worth noting that sailing is the only sport where no studies were found that reported on the loads of high-level athletes. All the studies on windsurfing, assumedly the most similar sport to dinghy sailing, reported internal load, particularly HR indices, while only one reported external load, specifically distance and speed (measured in competition).

Quality Assessment

The results of the quality assessment are presented in Table 4.4. Most of the studies were of fair quality (70%), none were of good quality and 30% of poor quality. Sixty-five per cent of the observational studies were classified as analytical, and the remaining 35% as descriptive observational studies. As a result, questions 6 – 14 were not considered applicable to the descriptive studies, unless the study included an analytical component. In this case, questions 5 and 14 were considered.

Table 4.3. Overview of studies included in the scoping review.

Authors	Surface Water Sport	Sample Size (n (sex))	Age (years) ($\bar{x}$ ± SD)	Level of Competition	Phase (Competition/ Training)	Monitoring Period	Monitoring Methods			Monitoring Outcome Variables	Training Load Category	
							Self-reported	Tracking	Performance testing		Int.	Ext.
Forbes et al. (2013)	Canoe polo	8 (M)	25 ± 1	International	Competition phase	Single session (championship)		X	X	HR indices, VT, VO2 indices, TMA, anaerobic power, strength (grip), flexibility (sit & reach)	X	X
Kenttä et al. (2006)	Kayaking	11 (6M:5F)	20 ± 1	Elite	Preparatory phase	3 weeks (training camp)	X		X	RPE, POMS, maximal strength (chins, dips, abs, bench press, bench pull), duration, sport-specific kayak performance test	X	X
Garatachea et al. (2011)	Kayaking	8 (5M:3F)	17 ± 2	International	All	42 weeks	X		X	RPE, POMS, RESTQ-sport, blood samples, maximal strength (bench press)	X	X
Borges et al. (2014)	Kayaking	10 (6M:4F)	17 ± 1	International	Recovery phase	7 weeks	X	X	X	HR indices, blood samples [La], sRPE, TRIMP, iTRIMP, VO2 indices, MAP, duration, distance, speed, on-water time trials	X	X
Caimmi & Semprini (2017)	Kiteboarding	5 (M)	34 ± 5	National	Competitive phase	Single session (regatta series)		X	X	HR indices, distance, speed & direction, frequency & duration of each beat, wind angle	X	X
Fiskerstrand & Seiler (2004)	Rowing	21 (M)	CD	International	All	30 years	X		X	VO_2 indices, blood samples, training volume, training type, rowing performance test	X	X

Table 4.3. Overview of studies included in the scoping review continued.

Messonnier et al. (2004)	Rowing	21 (M)	22 ± 3	International & national	Preparatory phase	Single session (7 – 13 sessions)	X		X	HR indices, blood samples [La], EE, duration, PAQAP questionnaire	X	X
Guellich et al. (2009)	Rowing	36 (M)	19 ± 1	International & national	All	37 weeks			X	HR indices, blood samples [La], VO_2 indices, duration, stroke frequency	X	X
Smith et al. (2011)	Rowing	20 (10M:10F)	M – 24 (21–30); F – 23 (19–31)	International (elite)	NR (Overload phase)	4 weeks x 2 (x 7 years)	X		X	Wellness questionnaire, blood samples [La], saliva samples, power output, training volume	X	X
Plews et al. (2014)	Rowing	9 (5M:4F)	NR	International (elite)	Preparatory phase	26 weeks			X	HR indices, blood samples [La], duration	X	
Tran et al. (2015a)	Rowing	14 (12M:2F)	26 ± 3	International (elite)	Specific preparation phase	4 weeks	X		X	HR indices, sRPE, iTRIMP, TRIMP, VO_2, VCO2, VT, RCP, T2minute, duration	X	X
Tran et al. (2015b)	Rowing	21 (14M:7F)	M – 28 ± 3; F – 32 ± 3	International (elite)	Specific preparatory & Competitive phase	6 months		X	X	VO_2, blood samples [La], T2minute, power output, weekly training frequency, duration, distance	X	X
Plews et al. (2017)	Rowing	4 (1M: 3F)	NR	International	Preparatory & Competitive phase	62 days		X	X	HR indices, distance, speed	X	X
Schram et al. (2016)	Stand up paddleboard	10 (6M:4F)	NR	National	Competitive phase	Single session (race)		X	X	HR indices, duration, speed, route/ distance	X	X
Farley et al. (2012)	Surfing	12 (M)	24 ± 6	National	Competitive phase	Single session (competition heat)		X	X	HR indices, distance, TMA, duration, number of paddling bouts, speed	X	X
Farley et al. (2018)	Surfing	41 (M)	23 ± 6	National	Competitive phase	Single session (competition series)		X		Distance, speed, duration, TMA		X

Table 4.3. Overview of studies included in the scoping review continued.

FernAndez-Gamboa et al. (2018)	Surfing	10 (M)	29 ± 11	National	Competitive phase	Single session (competition heat)	X	X	X	Distance (paddling & wave riding), percentage duration, velocity, RPE	X	X
Guevel et al. (1999)	Windsurfing	8 (M)	23 ± 3	International & national	Competitive phase	Single session (3 competitive regattas)		X	X	HR indices, blood samples [La], duration, wind intensity	X	
Chamari et al. (2003)	Windsurfing	10 (9M:1F)	21 ± 4	International	Competitive phase	Single session (competitive regatta)			X	HR indices, VO_2 indices, blood samples [La], wind intensity, duration	X	
Pérez-Turpin et al. (2009)	Windsurfing	45 (M)	30 ± 10	National	Competitive phase	Single session (race)		X	X	HR indices, speed, route/ distance	X	X

Abbreviations: [La]: blood lactate; CD: cannot determine; EE: energy expenditure; Ext.: external; HR: heart rate; Int.: internal; iTRIMP: individual training impulse; M: male; F: Female; MAP: mean aerobic power; NR: Not reported; PAQAP: physical activity questionnaire; POMS: Profile of mood state; RCP: respiratory compensatory point; RPE: rate of perceived exertion; sRPE: session-RPE; T2minute: time-in-zone approach; TMA: time-motion analysis; TRIMP: training impulse; VO_2: oxygen uptake; VT: ventilatory threshold

Table 4.4. Results for the quality assessment with Quality Assessment Tool for Observational Cohort and Cross-sectional Studies.

Authors	Study design	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Scoring (%)	Quality rating
Forbes et al. (2013)	Descriptive	Y	Y	CD	Y	N	NA	NA	NA	NA	NA	Y	NA	NA	NA	67	Fair
Senttä et al. (2006)	Analytical	Y	Y	CD	Y	N	Y	Y	Y	Y	Y	Y	N	CD	N	64	Fair
Garatachea et al. (2011)	Analytical	Y	Y	CD	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	71	Fair
Borges et al. (2014)	Analytical	Y	Y	CD	Y	N	CD	Y	N	Y	Y	Y	N	N	Y	50	Poor
Caimmi & Semprini (2017)	Descriptive	Y	Y	CD	Y	N	NA	NA	NA	NA	NA	Y	NA	NA	N	57	Poor
Fiskerstrand & Seiler (2004)	Descriptive	Y	Y	Y	Y	N	NA	NA	NA	NA	NA	Y	NA	N	N	63	Fair
Messonnier et al. (2004)	Analytical	Y	Y	CD	Y	N	N	N	Y	Y	Y	Y	NA	NA	Y	67	Fair
Guellich et al. (2009)	Analytical	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	79	Fair
Smith et al. (2011)	Analytical	Y	Y	CD	Y	Y	N	Y	N	Y	Y	Y	NA	CD	N	62	Fair
Plews et al. (2014)	Analytical	Y	N	CD	Y	Y	CD	Y	Y	Y	Y	Y	NA	Y	Y	77	Fair
Plews et al. (2017)	Descriptive	Y	N	CD	Y	Y	NA	NA	NA	NA	NA	Y	NA	Y	N	63	Fair
Tran et al. (2015a)	Analytical	Y	Y	CD	Y	Y	NA	Y	N	Y	Y	Y	NA	N	N	67	Fair
Tran et al. (2015b)	Analytical	Y	Y	CD	Y	Y	N	Y	Y	Y	Y	Y	NA	CD	N	69	Fair
Schram et al. (2016)	Descriptive	Y	Y	CD	Y	N	NA	NA	NA	NA	NA	Y	NA	Y	N	63	Fair
Farley et al. (2012)	Descriptive	Y	Y	N	Y	N	NA	NA	NA	NA	NA	Y	NA	NA	NA	67	Fair
Farley et al. (2018)	Descriptive	Y	Y	CD	Y	Y	NA	NA	NA	NA	NA	Y	NA	CD	N	63	Fair
FernAndez-Gamboa et al. (2018)	Analytical	Y	Y	CD	Y	N	N	N	N	Y	N	Y	NA	NA	N	42	Poor
Guevel et al. (1999)	Analytical	Y	Y	CD	Y	N	N	N	Y	Y	CD	Y	NA	N	N	46	Poor
Chamari et al. (2003)	Analytical	Y	Y	CD	Y	N	N	N	Y	Y	N	Y	NA	NA	CD	50	Poor
Pérez-Turpin et al. (2009)	Analytical	Y	Y	Y	Y	N	N	N	N	Y	N	Y	NA	NA	N	50	Poor

Abbreviations: Q: Question on NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies; CD, Cannot determine; N, No; NA, not applicable; Y, Yes; >80% = Good, 60-80% = Fair, and <60% = Poor; %: Percent

4.4 Discussion

Athlete monitoring assesses the effectiveness of the training program, minimizes the risk of developing non-functional overreaching or injury, as well as providing coaches, sport scientists and support staff with more confidence that they are applying the correct training stimulus for specific athletes [15,56]. This scoping review evaluated the methodologies used to monitor CLs and TLs of high-level competitive athletes in non-motorised surface water sports. Despite a thorough literature search, only 20 studies met the inclusion criteria. The included studies differed in methodology (monitoring measures) and number, sex and age of participants. Studies also differed in the duration of the monitoring period (ranging from a single session to 42 weeks).

Concerning loads for training and competition, the studies which did report HR-based methods, mostly reported on the training impulse method (TRIMP) [57] or the summated-heart-rate-zones method [58]. The utilisation of summated-heart-rate-zones is interesting, considering that the summated-heart-rate-zones method may have face validity but not criterion validity. However, half of the studies which considered TLs did not report HR-based methods. Athletes, coaches and sports scientists could learn about cardiovascular fitness and training by observing HR; therefore, HR indices are probably approaches that should be implemented more in surface water sports.

Some researchers have mentioned that HR-based methods may create discomfort (like in surfing) for the athlete and have suggested incorporating self-reported tools like RPE instead [51]. The session RPE (sRPE) method was used, but it was not as common as HR-based methods during non-motorised water sport. Also, RPE is not used as extensively when compared to other water (i.e. swimming) and land-based sports. Even though subjective self-report methods like RPE is more practical, less invasive and cost-effective compared to other load methods (i.e. blood samples and HR monitors), a critical downside to acknowledge is conscious bias during self-report measures. Specifically, an individual may respond in a way they deem to be socially desirable, and as a result, they appear to be coping when in fact they are not or vice versa [56]. Thus, when using self-report methods, it is essential to consider the design of the measure, how the data are collected, i.e. through the use of a mobile application or a hard copy in the form of a book, as well as the individual and situational factors which may influence the athlete.

In terms of external load measure, duration of the session or race was most often observed and reported. A possible explanation for this is that it is one variable a coach has control over in among the several uncontrollable factors in these sport types (such as the environmental conditions). There has, however, been a consistent increase in the utilization of GPS measures coinciding with the development of technology, both in team and individual sports. These technologies can monitor athletes' external workloads during training and competition. As a result, a coach or sport scientist can track the real-time workloads of athletes during training and competition and quantify their activity profiles, specifically in surface water sports. Additionally, TMA through video analysis is a method to determine time spent in specific modes of the sport, such as time spent paddling vs. surfing [50,59], and could be considered in future studies as a viable athlete monitoring method. Thus, while most studies considered distance and speed variables when measuring external load with GPS devices, duration seems to remain a useful determinant of TLs and CLs.

Only two studies (both on windsurfing) considered the environmental conditions (specifically wind intensity) and the effect these may have on the CL of the athlete [52,53]. Both studies showed that the percentage HR maximum values of windsurfers differ when comparing light (4-8 knots) and moderate (9-13 knots) wind intensities during a competition [52,53]. This is an important distinction to note that in similar sport types, there are environmental stressors which should be considered, and which add to the TLs and CLs of the athletes. Furthermore, neither of these two studies explored strong wind conditions (≥16 knots). Thus, wind intensity may be a possible external load for wind-powered surface water sports, which future studies could explore.

The authors did not find any athlete monitoring studies on any high-level sailors. This is surprising considering the popularity of competitive sailing as a non-motorised surface water sport and an event contested at the Olympic Games. Studies on the demands of competitive sailing are lacking. Future studies should investigate the loads that high-level sailors are exposed to during training and competition.

In addition, most studies did not consider age and sex as a confounding factor. Firstly, due to physical and physiological differences associated with different ages, studies should consider youth athletes on their own and determine if the same athlete monitoring methods apply to them as to adult athletes. Furthermore, male and female athletes are unique, and differences in training responses between sex should be considered as they may be different.

A limitation of the studies included were small sample sizes (ranging from 4 to 45 participants). Two studies could be considered case studies but were included as they fulfilled the predefined inclusion criteria [32]. Another study by Ballegaard and colleagues [55] was excluded as the authors compared two sailors (one boat) to the average top performers in various international regattas. Conversely, if considering that these studies only include a select population of high-level competitive participants, then the small samples are probably admissible. The lack of justification of sample sizes and estimates of effect size, as well as the consideration of the effects of potential confounders, were the main methodological shortcomings. While the most frequently unreported aspects were ‘the participation rate of eligible persons’ and the ‘loss to follow-up after baseline’. Notably, the strengths included an accurate description of the research question or objectives, describing the study population as well as the exposure and outcome measures clearly.

Scoping Review Limitations

This is the first scoping review to map out the methods currently being used in the field of athlete monitoring in non-motorised surface water sports. However, this review has only considered high-level, competitive athletes, performing at a national or international level. Furthermore, the review has not considered any studies which included an intervention. As such, the conclusions are not generalisable to sports beyond the scope of this review. Lastly, it was difficult to review the quality of descriptive non-analytical observational studies.

Practical Applications

This systematic review highlights that wearable technology such as HR and GPS monitors are being used successfully in TL and CL monitoring of athletes in non-motorised surface water sports. Furthermore, this review shifts the focus from field-based team- and running-based sports to non-motorised surface water sports and aims to provide coaches, athletes, sports scientists and support staff with information relating to the methods used to monitor athletes competing in non-motorised surface water sports.

4.5 Conclusion

The most commonly used methods to monitor TLs and CLs in competitive non-motorised surface water sports in the specific categories include: self-report measures – session RPE; tracking measures – duration; performance testing – HR-based methods.

To summarise, the review provides support for sport scientists, coaches and researchers to use a mixed-method approach to monitoring, whereby both internal and external load measures are included, such as duration and HR-based methods. Additionally, more research is needed on female and youths in the respective non-motorised surface water sports, since these are athletes that are unique and under-represented in the current literature.

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CHAPTER 5: ARTICLE THREE

Quantifying Training Loads of Competitive South African Optimist Sailors in Different Wind Intensities

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ABSTRACT

Introduction: More effort is required from a sailor during stronger wind intensities (WI(s)). The extent to which WIs influences the amount of stress (training load; TL) imposed on the sailor is unclear. Therefore, the primary aim of this study was to describe and compare TLs of Optimist sailors in different WI conditions during on-water training sessions. Secondary aims were to use estimated energy expenditure (EE) as a criterion to compare different TL measures within the different WIs. *Methods:* Twelve competitive Optimist sailors (n = 8 boys, 4 girls) were monitored during 21 sailing training sessions in light, medium and strong WI exposures. Main outcome variables included Training Impulse (TRIMP), Summated-Heart-Rate-Zone score (SHRZ), session rate of perceived exertion (session-RPE), and session duration. *Results*: Sailors' EE were higher during strong compared to light and moderate WIs ($p < 0.01$). TRIMP (Median: 104 vs. 99 AU) and session-RPE (Median: 479 vs. 328 AU) ($p < 0.05$) TLs were higher in strong compared to light WIs. Conversely, the HR-based methods were highest in medium WI (Median: TRIMP=120 AU; SHRZ=246 AU). More time was spent in SHRZ zones 4 and 5 during stronger compared to lighter WIs ($p < 0.05$). Correlations between EE and TL variables were between *rho* = -0.36 and 0.61 ($p < 0.01$). *Conclusion:* These findings demonstrate that an increased effort is required to sail an Optimist dinghy in increasing WIs. It is, therefore, necessary to monitor the TLs of Optimist sailors in different WIs to be sure the athlete is optimally adapting to the training stimulus, as well as not becoming overloaded.

Keywords: *training load, Optimist sailing, session-RPE, TRIMP, wind intensity*

5.1 Introduction

Training loads (TLs) in team sports have been extensively researched to determine the optimal balance between load and recovery in order to enhance performance [1-6]. It is therefore surprising that, besides endurance sport, relatively little research on TLs have been conducted on individual sports, and specifically non-motorised surface water sports such as sailing (Chapter 4). Understanding the response an athlete has to specific training is necessary to guide and optimize the training program; albeit to ensure optimal adaptation and performance enhancement or to reduce injury risk [2,7-9].

The environmental conditions within which performances takes place may impact the load imposed on the athlete [10-12]. Sailing, specifically, is made ever more challenging since the context of the sport is inherently uncertain and unstable [13]; in that the participants are constantly facing unpredictable variables, such as the wind, waves and actions of the other boats [14]. Undoubtedly, the physical and physiological demands in sailing vary depending on the environmental conditions (such as wind intensity (WI)), exercise intensity, frequency and duration, as well as the type of sailing class [15]. For instance, one of the leading contributing factors in the development of fatigue in dinghy sailors is the hiking technique [15-18] and sailors generally begin to hike when the WI approaches 12 knots (kts) [19].

An Optimist is a solo sailing dinghy meant for children up to the age of 15 years; is considered one of the most popular sailing dinghy classes in the world, and recognised, by the International Sailing Federation, as an international class. It is estimated that there are between 130 000 [20-21] and 150 000 registered youth in about 100 to 120 countries which take part in Optimist sailing over the world (www.optiqld.org.au). Racing in the Optimist sailing class dinghy is held in WIs between 4 and 24 kts, and are contested over a predetermined course, where the race committee aim to have the leading boats completing the course within 50 minutes after the start [22]. The racecourse distance is calculated based on the existing environmental conditions, for example a race taking place in a stronger WI (i.e. 16 kts) will result in a longer course distance, (as the boats will sail faster) when compared to a lighter WI (i.e. 8 kts). To prepare for these sailing races, it is necessary for Optimist sailors to undertake sport specific on-water training to develop the necessary skills and muscular fitness to perform well during competition. However, the diversity of the training environment and structure within the sport make it inherently difficult to compare the TLs of the sailors and their subsequent response within the sessions. While, the external loads (such as distance and speed) of the sailors can be determined and compared during a race (Chapter 5); the influences of the various activities (such as practicing starts) make it challenging to promote the use of these methods. Therefore, it is necessary that the methods used to determine TLs in sailing can account for the activities, as well as the environmental factors [10].

Recent developments in micro-technologies are providing the means to quantify athlete responses during training and competition [23]. For example, heart rate (HR) monitors provide objective data relating to the internal TL of an athlete. Currently, in non-motorised surface water sports, HR measures are the most commonly used objective methods for monitoring internal TL of athletes (Chapter 4). In comparison, the session rate of perceived exertion (session-RPE) method, proposed by Foster and colleagues [24], has been deemed a practical tool for determining subjective internal TL [11]. Previous studies have shown a favourable relationship between session-RPE and other more complicated methods involving HR indices in individual sports [10,24-25]. Nevertheless, self-reported session-RPE cannot replace HR methods completely [11] and may be limited under various environmental conditions [11,26]. Additionally, session-RPE should probably not be used in isolation when monitoring TL in youth sports [2]. Importantly, the use of session-RPE has not been reported in Optimist sailing studies to date, and, when deciding which method to use, it is essential to note the practical application of the method within the training environment [10].

To date, a few studies have looked at the physical and performance demands of sailing [12,15,17,21,27-29]. A large proportion of the sailing research has been done in a laboratory setting; an apparent reason being that the nature of the unpredictable and markedly wet environment can result in loss of data and possible equipment failure. Nevertheless, simulated studies do not always reflect the on-water responses [12]. Consequently, naturalistic observations are needed, specifically in Optimist sailing. However, the authors were unable to find research investigating the TLs competitive Optimist sailors are exposed to during an actual on-water sailing training session; specifically, when comparing these training sessions in different WIs (light, medium and strong). There are three studies which have investigated the association between cardiovascular and metabolic responses of Optimist sailors in various WIs. Two of the studies included simulated on-water upwind sessions during 7 to 18 kts [20] and 8 to 12 kts [30]; while another study [21] made use of simulated upwind trials on an ergometer (> 15 kts). Their results confirmed that cardiorespiratory, -vascular and metabolic responses in Optimist sailors are linearly related to WIs during upwind sailing. In addition, Callewaert and colleagues [21] also investigated the mechanisms contributing to the onset of muscle fatigue in optimist sailors. These studies focused only on the upwind leg (as sailors spend most of their time in the upwind leg during a regatta (Chapter 3)) and mostly on the hiking position but not on the demand of other sailing manoeuvres or points of sail. Additionally, previous studies did not include actual real on-water training sessions (which involve more than just upwind sailing), nor made use of typical TL measures, as the focus was not on athlete monitoring.

Considering that exercise intensity is variable as a result of unstable contextual and environmental conditions. It is hypothesised that WIs will act as an external stimulus applied to the sailor, thereby contributing to internal load (physiological and psychological response) imposed on the sailor.

Therefore, the main aim of this study was to describe and compare indices of training stress (i.e. Training Impulse (TRIMP), Summated-Heart-Rate-Zone Score (SHRZ), session-RPE, and session duration) of Optimist sailing training sessions during various WI conditions (i.e. light, medium and strong WIs). Secondly, this study aimed to determine the relationship between estimated energy expenditure (EE) and these TL measures in the different WIs. The information gained through the determination of TLs may have an extensive practical impact on the development of scientific coaching and training practices in Optimist sailing and training.

5.2 Materials and Methods

Participants

Twelve (n = 8 boys, 4 girls) South African Optimist sailors (age 12 ± 1 years; body mass 44.6 ± 8.5 kg; competitive sailing experience 3 ± 2 years; training volume 6 ± 2 hours/week) volunteered to participate in the study. The study exclusively considered high-level competitive South African Optimist sailors, between the ages of 11 and 15 years, who had competed in at least one National or International Optimist regatta within the past year. At the time, only 34 possible Optimist sailors within South Africa met the inclusion criteria of this study; as a result, the sample of participants who volunteered for this study make up 35% of the population. Written informed assent and consent was provided, and the institutional research ethics committee approved the study (SU-HSD-003396).

Research Design and Procedures

In this observational study, participants were monitored during 21 on-water sailing training sessions in varying WI conditions. The coaches determined all training sessions beforehand, and the researchers did not make any changes to the planned training.

During a land briefing, the sailors were familiarised with the subjective Category Ratio scale (CR-10 RPE) [24] and the session-RPE protocol was explained. Participants were encouraged to ask questions in case of confusion. Heart rate was monitored via a chest-based HR monitor (H10, Polar Electro®, Kempele, Finland) which is valid and reliable for HR monitoring in the field [31]. The HR monitor was placed on the sailor's chest, under their wetsuit, before launching. Heart rate was recorded at one second intervals. After each session the HR monitor was synced with the relevant mobile application (Polar Beat® version 3.3.7, Electro Oy, Kempele, Finland) and data were downloaded and HR indices analysed. The CR-10 RPE were recorded within 30 minutes after returning to shore, which was done to avoid feelings of easy or hard training immediately after the termination of the session [24,32]. On returning to the shore, each sailor was asked: "how hard was the whole session?" [24].

After each session the training loads and the indices of training stress, during the three WI sessions, were quantified.

Quantifying Training Load

Training load measures were determined through Banister's [33] training impulse (TRIMP) method, the SHRZ method [34] and the session-RPE method [24]. Additionally, duration, in minutes, was included as a measure of external TL. While EE was calculated to determine the amount of work completed [35] and used as the concurrent criterion measure [36] to compare to the TL measures.

Banister's training impulse (TRIMP) method [33] considers the mean HR response (expressed as resting (HR_{rest}), exercising (HR_{ex}) and HR maximum (HR_{max})), session duration, and a sex-based coefficient in a calculation to determine an individual's response to training [11]. Where ΔHR ratio is the difference in mean HR_{ex} and HR_{rest} compared to the difference in HR_{max} and HR_{rest}. Wallace and colleagues [25] deemed Banister's TRIMP method as valid (*r* = 0.65).

For male athletes:

$$TRIMP = \text{duration (minutes)} \times \Delta HR\ ratio \times 0.64 \times e^{1.92 \times (\Delta HRratio)} \quad \text{……………………..…………...(1a)}$$

For female athletes:

$$TRIMP = \text{duration (minutes)} \times \Delta HR\ ratio \times 0.86 \times e^{1.672 \times (\Delta HRratio)} \quad \text{…………………..…………..(1b)}$$

Edward's SHRZ method calculates the amount of training time (minutes) spent in each of the five pre-determined HR zones (determined from HR_{max}) [34]. Although this method has not been validated against any objective physiological assessments; owing to its face validity, the SHRZ method has been used by many studies in a range of sports as a good determinant of TL [26]. Consequently, the present study only uses this method for descriptive purposes. Age predicted HR_{max} values were calculated using Tanaka's equation [37-38]. Tanaka's equation closely predicts mean HR_{max} in children and adolescents [39].

$$HR_{max} = [208 - (0.7 \times age)] \quad \text{………………………………………………………………….....(2)}$$

In line with Edwards [34] methods the zones were established as: zone 1 (50 – 60% HR_{max}), zone 2 (60 – 70% HR_{max}), zone 3 (70 – 80% HR_{max}), zone 4 (80 – 90% HR_{max}) and zone 5 (90 – 100% HR_{max}) (Borresen & Lambert, 2008). Training time spent at <100 beats/min (bpm) was excluded from analysis [40]. The respective TL was then calculated using a coefficient for each zone.

$$Summation = (\text{duration in zone } 1 \times 1) + (\text{duration in zone } 2 \times 2) + (\text{duration in zone } 3 \times 3) + (\text{duration in zone } 4 \times 4) + (\text{duration in zone } 5 \times 5) \quad \text{………………………………..……………..(3)}$$

The session-RPE method quantifies internal TL by multiplying the total duration of the related session (minutes) by the self-reported subjective load (CR-10 RPE) for each training session. The calculated session-RPE, and the subsequent TL, is expressed as an arbitrary unit (AU). Validity and reliability of session-RPE for monitoring exercise training intensity is reported by Herman and colleagues [41] ($r = 0.88$).

$$\text{Session-RPE (AU)} = \text{CR-10 RPE} \times \text{duration (minutes)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Estimated EE is a valid means ($r = 0.86$) to equate the amount of work completed at submaximal exercise [36]. The equation used in the current study factors in the person's sex, weight, age and HR_{ex} of the training session.

$$EE = sex \times (-55.0969 + 0.6309 \times HR_{ex} + 0.1988 \times weight + 0.2017 \times age) + (1 - sex) \times (-20.4022 + 0.4472 \times HR_{ex} - 0.1263 \times weight + 0.074 \times age) \ldots\ldots\ldots\ldots(5)$$

Where sex = 1 for males and 0 for females. The benefit of using the equation above is that the user does not need to have a measure of the athlete's fitness. However, HR reserve was calculated [42] and included as a descriptive estimation of cardiovascular fitness.

Environmental Conditions

Wind intensity measures were recorded using an impeller anemometer (SM-18, WeatherHawk, USA) located at a height of 2 meters on the rubber inflatable boat in the respective training area. The WI recordings were taken at the beginning of the session and every 30 minutes thereafter for the full duration of the session. The average of the wind recordings for the duration of the session was used to categorise the training session as light (0-8 kts), medium (9-16 kts) or strong (17-24 kts); comparable to previously reported WIs categories [43].

Data Recording

The HR data were exported from the online platform (Polar Flow, Polar Electro, Kempele, Finland) into Microsoft Excel® 2016 (Microsoft Corporation, Washington DC, USA) for further analysis. Data were filtered by removing the first five and final ten minutes of the recorded HR data; this was to eliminate the time spent launching and returning. Therefore, only the data of the training session was included in the analysis. For each session, the total and relative time spent in the SHRZ were calculated, the minimum recorded HR in the training session (HR_{min}), the mean HR for the session (HR_{ex}) and the peak HR during the session (HR_{peak}) were also recorded.

Statistical Analysis

Statistical analysis was performed in Microsoft Excel® using the XLSTAT add-in (Version 2019.3.2, New York, USA). Data were checked for normality using the Shapiro-Wilk test. All non-parametric data are presented as median and interquartile range (IQR) and parametric data as mean ($\bar{x}$) ± standard deviation (SD). Data were first analysed for the group overall, then grouped based on the three WI categories. For all data, Kruskal-Wallis and Mann-Whitney tests were used to compare any differences between WI categories within the TL methods. All the TL measures were additionally compared to EE by assessing the level of correlation, using a Spearman Rank (*rho*) correlation with 95% confidence intervals (95% CI) and coefficients of determination (*R*). Correlations were categorised according to the following thresholds; *rho* = <0.10 = negligible, 0.10-0.29 = small, 0.30-0.49 = moderate, 0.50-0.69 = large, 0.70-0.89 = very large, 0.90-0.99 = nearly perfect, 1.0 = perfect [44]. Alpha level was set at 0.05. Lastly, interactive dot plots showing median differences over the % HR zones and individual data points were used to transparently illustrate the distribution of the data [45].

Prior power calculations with G*Power version 3.1.9.3 or Windows [46] for a moderate effect size (r^2 = 0.5; ρ = 0.71) set at a power of 80% (β of 20%) and α-level at 5% suggest a total sample of 11 participants for correlations, and for difference between WIs set at a large effect size (f = 0.40) a total sample of 66 recordings were required.

5.3 Results

A total of 68 recordings were collected from 21 sailing training sessions; with 24 recordings in light (6 ± 2 kts), 26 in medium (12 ± 3 kts) and 18 in the strong (20 ± 3 kts) WI categories. Individual recordings were excluded from the analysis if the sailor did not complete the entire training session (n = 1), or if no measure of the load was recorded. For example, HR data was not recorded due to equipment malfunction (n = 45) or accidental deletion (n = 1). Table 5.1 shows the descriptive characteristics of all the training sessions. Training type in each session varied between biomechanics (i.e. body position transition between the WIs), boat set up (sail setting changes), boat handling (tacking and gybing), straight-line speed, modified starts and short races (10 to 12 minutes).

Table 5.1. Descriptive characteristics of the sailing recordings (n = 68) between wind intensities in which the participants were monitored.

	Light WI (n = 24)			**Medium WI (n = 26)**			**Strong WI (n = 18)**			***P-value***
	Median	IQR		Median	IQR		Median	IQR		
		25%	75%		25%	75%		25%	75%	
Energy Expenditure (AU)	$32^{a,b}$	27	35	$44^{b,c}$	35	51	$45^{a,c}$	40	52	<0.01
HR_{min} (bpm)	83^{a}	77	93	92^{b}	84	98	$95^{a,b}$	87	118	<0.01
HR_{ex} (bpm)	$120^{a,b}$	117	132	141^{b}	128	153	142^{a}	134	157	<0.01
HR_{peak} (bpm)	$171^{a,b}$	160	178	183^{b}	175	192	185^{a}	180	192	<0.01
$HR_{reserve}$ (bpm)	129	125	134	129	126	130	129	125	130	0.99

* IQR = interquartile range; bpm = beats per minute; AU = arbitrary units.

^{a,b,c} categories with matching letters are significantly different from one another ($p < 0.05$).

Median TL (IQR) for all sessions was calculated at 95 (59-128) AU, 222 (1501-306) AU and 438 (292-598) AU for TRIMP, SHRZ and session-RPE, respectively. No differences were observed between the TL methods (TRIMP, SHRZ and session-RPE) overall ($p > 0.05$). However, session-RPE was reported as higher in strong compared to light WI ($p = 0.02$). Table 5.2 shows the median (IQR) TLs within each WI category.

Table 5.2. Training load variables of the sailing training sessions (n = 68) between wind intensities.

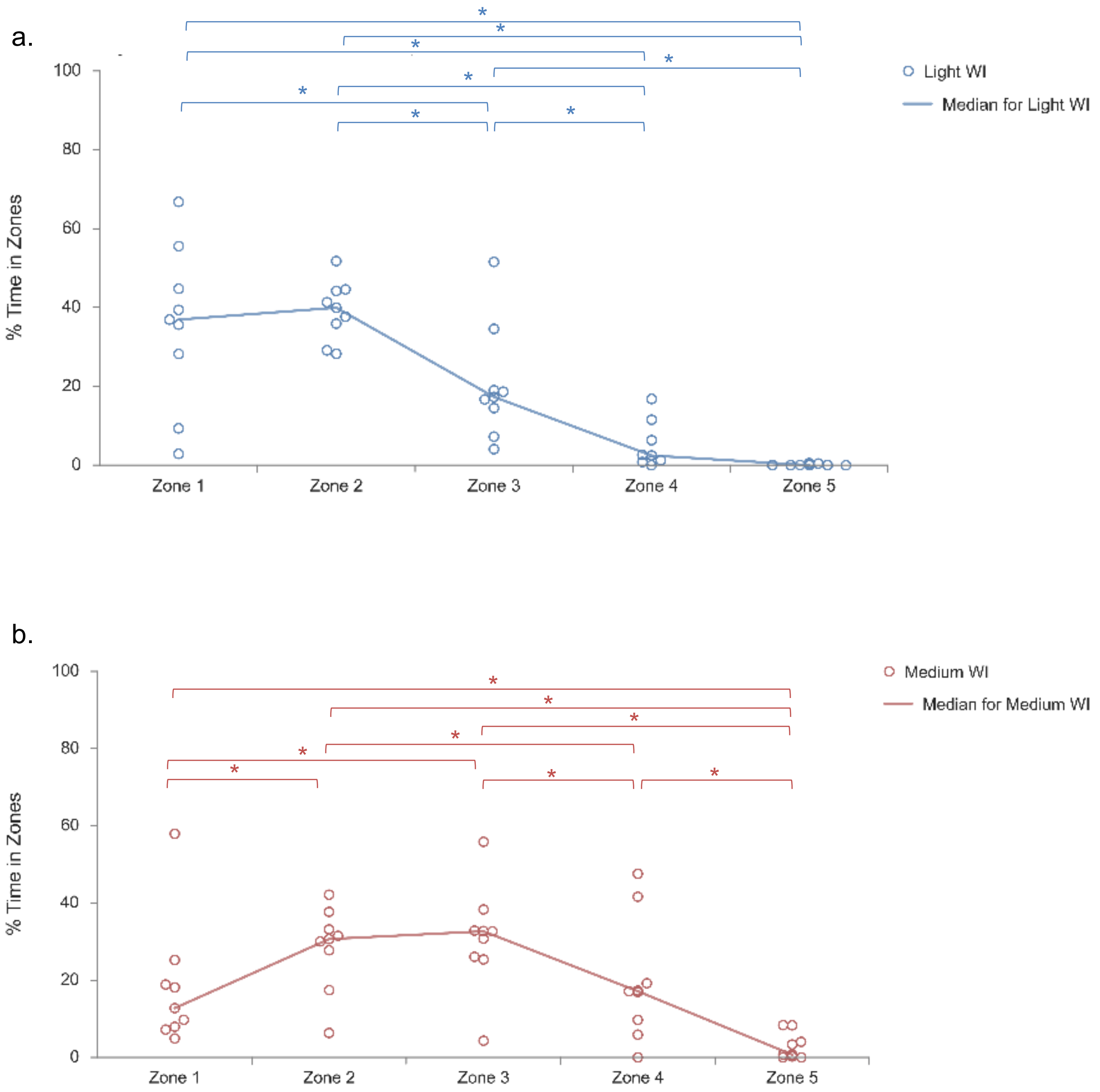
	Light WI (n = 24)			**Medium WI (n = 26)**			**Strong WI (n = 18)**			***P-value***
	Median	IQR		Median	IQR		Median	IQR		
		25%	75%		25%	75%		25%	75%	
Internal Training Load Measures										
TRIMP (AU)	99	57	145	120	60	199	104	94	132	0.86
SHRZ (AU)	226	148	330	246	136	339	217	179	246	0.67
Session-RPE (AU)	328^{a}	294	459	463	264	681	479^{a}	348	678	0.09
External Training Load Measures										
Session Duration (minutes)	$147^{a,b}$	110	156	$94^{a,c}$	89	133	$73^{b,c}$	60	99	<0.01

* IQR = interquartile range; RPE = rating of perceived exertion; AU = arbitrary units; TRIMP = training impulse; SHRZ = summated-heart-rate-zones

^{a,b,c} categories with matching letters are significantly different from one another ($p < 0.05$).

While, the duration of the sailing training sessions ranged from 40 to 264 minutes, differences were observed in session duration between all three WI categories ($p < 0.05$), with strong WI representing the shortest duration.

Figure 5.1 shows the median percentage of training time spent in each HR zone derived from Edwards SHRZ. There are significant differences between the light and medium and light and strong WI in all five zones ($p < 0.05$). Overall, the sailors spent the majority of the total training time in zone 2 (31%; aerobic system) and zone 3 (26%; anaerobic glycolysis system).



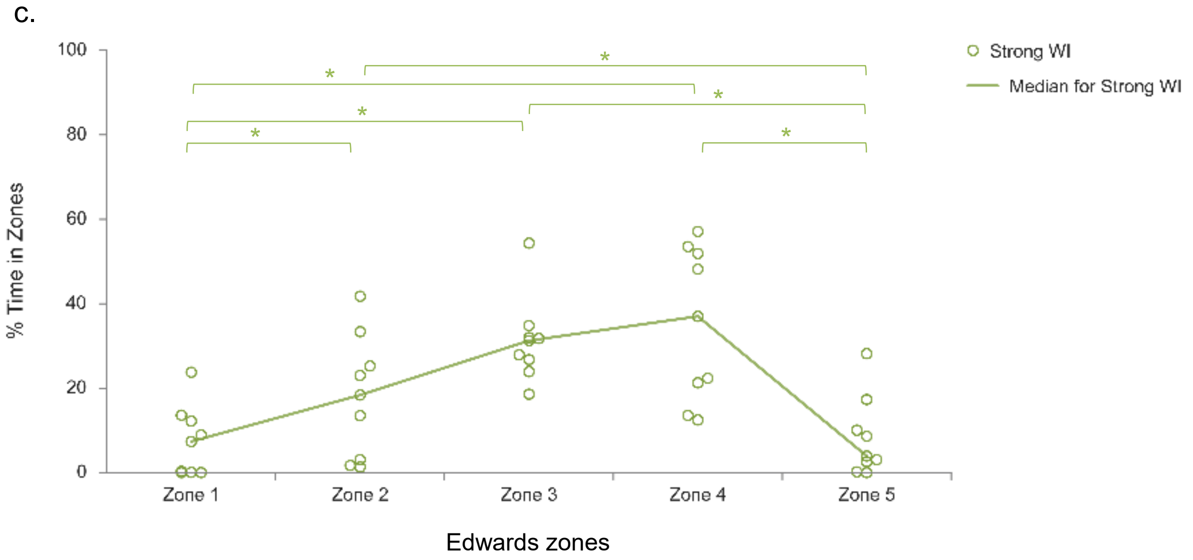


Figure 5.1. Medium percentage time spent in each HR zone within each wind intensity (a. = light, b. = medium, c. = strong) (* $p < 0.05$).

The relationships between EE and the four TL measures are shown in Table 5.3. All correlations were significant ($p < 0.01$).

Table 5.3. Correlations coefficients (*rho*) between energy expenditure and training load methods within the wind intensity categories.

	Correlation Coefficients		
	rho	95% CI	*R*
Energy Expenditure vs TRIMP			
ALL sessions	0.61^{L}	0.42 – 0.75	0.37
Light	0.82^{VL}	0.57 – 0.93	0.67
Medium	0.76^{VL}	0.48 – 0.90	0.57
Strong	0.35^{M}	-0.15 – 0.71	0.12
Energy Expenditure vs SHRZ			
ALL sessions	0.46^{M}	0.24 – 0.64	0.21
Light	0.86^{VL}	0.66 – 0.95	0.74
Medium	0.76^{VL}	0.49 – 0.90	0.58
Strong	-0.31^{M}	-0.68 – 0.20	0.10
Energy Expenditure vs Session-RPE			
ALL sessions	0.04^{N}	-0.20 – 0.28	<0.01
Light	0.18^{S}	-0.25 – 0.54	0.03
Medium	-0.02^{N}	-0.41 – 0.37	<0.01
Strong	-0.71^{VL}	-0.90 – -0.31	0.51

Table 5.3. Continued.

Energy Expenditure vs Duration			
ALL sessions	-0.36^{M}	-0.56 – -0.12	0.13
Light	0.30^{M}	-0.13 – 0.63	0.09
Medium	0.23^{S}	-0.18 – 0.57	0.05
Strong	-0.75^{VL}	-0.92 – -0.39	0.57

* CI = confidence intervals; *R* = coefficients of determination; *rho* – Spearman correlation coefficient; Session-RPE = session-rating of perceived exertion; SHRZ = summated-heart-rate-zone; TRIMP = training impulse

^{N}: negligible; ^{S}: small; ^{M}: moderate; ^{L}: large; ^{VL}: very large

5.4 Discussion

Since the suggestion that TL is related to performance improvement and injury risk [1], the quantification of TL has become a key aspect in training program development and in the follow-up of the respective athletes. However, despite the many sailors training and competing in the Optimist class across the globe, there remains very little data available on their TLs during an actual on-water training session. The main findings of this study show that Optimist sailors experience higher TLs during stronger WIs, and while session-RPE is sensitive enough to identify perceived TL differences between light and strong WIs, TRIMP may be used as a TL measure in Optimist sailors since it relates to EE during all WIs.

Average HR$_{ex}$ was similar or slightly more elevated compared to previous Optimist sailing studies [21,30] within similar WI and RPE ranges. These trivial differences may be attributed to the naturalistic setting and the individual differences between sailors. While the HR$_{peak}$ was comparable, within similar WI, to the on-water simulation study by Lopez and colleagues [20]. All HR indices, as well as estimated EE, were higher in the stronger WIs (17-24 kts). These results are supported by previous research which suggest that Optimist sailors do more work and is placed under more TL (stress) as WIs increase [20-21,30]. With an increase in WI, a resulting increase in force is placed on the sail. Thus, the sailor needs to exert more effort (i.e. hike harder) to maintain the counterbalance and keep the boat upright [13]. In other words, the sport shifts from manipulating the environmental context to trying to control the boat as the WIs increase.

Furthermore, the WI also influenced the overall duration of the sailing training session, with light WI sessions being held for nearly twice as long as strong WI sessions. When scrutinising the TL measures used, the results seem contradictory. Specifically, in that TRIMP and SHRZ both report higher, albeit not statistically significant, values in the medium compared to the stronger WIs. This is likely because the session duration in light and medium WIs are longer when compared to the strong WI sessions. Therefore, this finding is not surprising, considering that both of these TL measures are time-dependent (duration) calculations [2]. One could argue then, why would the session-RPE results be any different, since it also takes into account duration. However, considering the correlations where session-RPE doesn't relate strongly to EE except during strong WIs; we propose that, due to the subjective nature of the session-RPE measure, the higher perceptual rating in stronger WIs may have more bearing on the actual TL of the sailor in the session than the duration. The 2013 consensus statement on overtraining syndrome (European College of Sport Science) supports this, as the panel suggest that psychological indicators (like session-RPE) are more sensitive and consistent than physiological measures in overtraining studies [47].

While, session-RPE methods have been deemed useful for evaluating and determining internal TL in most endurance-based sports [25], an alternative possibility is that session-RPE is not appropriate for youth Optimist sailors. The participants in Optimist sailing are relatively young and as suggested by Bourdon and colleagues [2], their ability to assess their perception of effort is often unreliable. Additionally, the young sailors may have perceived the stronger WI sessions to be more intense due to heightened anxiety or possible fear while sailing in these conditions. Whereas, Impellizzeri and colleagues [48] proposed that the physiological and performance outcomes of athletes after training may depend on fitness characteristics of the athletes. Thus, the sailor's perception of effort within the session may have been more dependent on their fitness or lack thereof within each session [49-50]. To consider this, $HR_{reserve}$ was calculated and compared as a measure of cardiovascular fitness. There were no differences in the fitness levels of the sailors; however, if all the sailors were equally unfit, this might explain the higher RPE ratings in the stronger WI sessions. On the other hand, a few of the participants suggested that while they hadn't physically worked hard, they reported feeling tired from concentrating after the session in light wind. Further studies should consider the relationship between the fitness, psychological measures and TLs in Optimist sailors.

It would not be uncommon for TL measures to over- or under-estimate the load in the different conditions, a suggestion could be to explore the use of a WI-specific session-RPE measure which would be a self-reported monitoring tool that also reflects the external load brought about the WIs during a training session for sailors. It has been suggested that RPE is influenced more by resistance load than by volume [51]. Consequently, we suggest that perceived session load (by the sailor) would be reflected more specifically by adding the WIs (in kts), similar to adding number of repetitions performed in resistance exercise to RPE for session-RPE [52-53]. This possible measure should be investigated in non-motorised surface water sports.

To establish which of the specific TLs have a stronger relationship with the amount of work done in (or effort put into) a training session under various WIs, estimated EE was used as a criterion. Lopez and colleagues [20] made use of objective assessments to assess cardiac output, blood pressure and

HR, along with an estimated on-water oxygen consumption, for cardiovascular and metabolic responses in WIs ranging between 7 and 18 kts. Even though the EE used in the present study is a projected measure, it does align with Lopez and colleagues' objective assessments. The moderate to very large relationships showed that TRIMP is probably the best TL method to incorporate into the sailors' sessions. The SHRZ method is also an option, but future studies should first rigorously validate this method. These findings are not surprising as both TRIMP and SHRZ are HR-based TLs.

Previously, Laser sailors have shown a shift from aerobic metabolism into anaerobic glycolysis during upwind sailing in WI over 20 kts [54] and as duration increases to about 18 minutes in a fatigue protocol with Optimist sailors (> 15 kts) [43]. While, others have found that there is only a small oxygen and energy deficit during upwind hiking under 20 kts and 15 minutes with blood lactate concentrations under 4 mmol.l^{-1} [55-56] that may also be attributed to muscular recovery during intermittent rest intervals [21]. Nevertheless, blood lactate concentrations were not assessed during the training sessions of the present study. Therefore, we are unable to accurately determine the metabolic contribution during various WIs. Though, the SHRZ illustrates the probable shift from aerobic metabolism in light WIs (6 ± 2 kts) to anaerobic glycolysis and ATP-phosphocreatine during strong WIs (20 ± 3 kts). A possible explanation for this is that skilled Optimist sailors constantly adjusted their body during the strong WI (more than in light WI) for more control over the boat, which may increase the metabolic demand. Which is also reflected in the elevated HR response. This highlights the benefit Optimist sailors will gain from higher levels of aerobic fitness, as well as sport specific muscular endurance training. By increasing the aerobic fitness, a sailor may take longer to reach the anaerobic threshold; thus, a higher intensity can be maintained (for example in a strong WI session). The zones of the SHRZ method may give coaches a better understanding of the energy system that dominates in the various WIs and could guide more effective training programs if validated.

Ultimately, WI is a substantial factor which significantly influences the TL of the sailor and should be considered when sailors are training, in particular, stronger WIs. However the nature of the session, for instance doing intermittent work during training sessions (where some sailing drills involve stop-starts and various changes in directions), or continuous sailing for a set duration, in addition to all the possible external factors that may affect sailors' physical and physiological response, may have also contributed to these findings as well. Unfortunately, due to the small sample size, the type of session could not have been taken into consideration for additional analysis and future studies should investigate this.

Researchers have indicated the need for load monitoring to consider both external and internal load measures [11,57]. Where, methods that assess internal load or indices of training stress indicate how athletes are adapting and managing external loads, and even though external load provide useful information, monitoring the internal load should be the main priority, particularly in sailing as the effort put in may determine for example the boat speed. Thus, this study included duration as a measure of external load along with the various internal load measures. This decision to include duration over other external metrics such as distance and speed was made for practical reasons. For the most part, when monitoring TLs of sailors, the internal TLs seem more critical, since the boat is covering the distance or maintaining a specific speed. Thus, unless the training session is aimed at comparing boat speed or testing speed with other sailors, it is not essential to measure these variables in a training session. In contrast, the duration of a session has more bearing on the sailor, in that the sailor is required to maintain a specific work output over the course of the training session. Additionally, more time spent sailing will ultimately result in more EE and a higher TL. Future studies could standardize the duration of the training sessions, to establish whether a real change in TLs are produced. However, this may be unrealistic in real-life training scenarios, in which sessions varying in duration based on the aim and drill type.

In conclusion, WIs apply an external stimulus to the sailor, thereby contributing to internal load (physiological and psychological response) imposed on the sailor, especially when comparing strong and light WIs. On one hand, calculation of training impulses (TRIMPs) to quantify internal TL can be considered. However, it should be used conservatively as it includes HR as a variable. While previous research in kitesurfing have used HR to determine intensity [58]. Using HR measures in sailing, a quasi-isometric sport, may not reflect the same response as that associated with a dynamic sport such as soccer or rugby. Perhaps sport scientists and coaches should adopt a sailing specific indoor fitness test to validate the correlation between HR with oxygen consumption. It is important to highlight that sport scientists and coaches should be cautious when using HR as a monitoring tool or comparing loads of sailors to those of athletes in other sports. Particularly considering the uniqueness of different sports, sailing for example is quasi-isometric and not dynamic, therefore the HR may respond differently. Contrarily, the sRPE is a simple and practical tool that represents the sailors' own perceptions of training stress, including both physiological and psychological stress. The sRPE has shown to be a valid indicator of intensity in different sports and sometimes a more valid marker of exercise intensity in these sports over a broad range of activities than HR monitoring. More research is required to validate HR and RPE for sailing specifically.

Study Limitations

Some limitations of the present study should be acknowledged. Firstly, the results from the present study, may be generalised to similarly matched Optimist sailors training in WIs similar to those in the training sessions analysed here. Furthermore, other environmental or contextual conditions i.e. temperature, currents, waves and actions of the other boats were not assessed. Therefore, we cannot estimate the contribution these may have had on TL.

Secondly, the data from the sailors are limited to the duration and specific drills included in the respective training sessions. The time spent in each activity did not represent or simulate a race; however, it does give an indication of the TLs one can expect during a sailing training session in each respective WI. The EE measured during a typical sailing training session provide some insight into the amount of effort each sailor put into the session; however, they are not necessarily typical of all responses expected by all participants of sailing in all conditions. Also, EE was only an estimation, future studies should compare these results with direct measures. The use of the SHRZ methods to determine internal TLs is limited in that it does not exclude pause time within the session (for example time spent waiting between drills or while waiting for a start). However, this is difficult to differentiate since sailors are required to stop their boats and attempt to maintain a position on a start line prior to the start of a race. For the purpose of the present study the number of intervals and specific drills included in each training session were relatively less important than the overall TL score. Lastly, the SHRZ method does not include values above 100% or below 50% HR_{max}.

Additionally, the sample size was perhaps too small to detect small to moderate differences between the WIs. However, keeping in mind that this is a very specific group of sailors, the sample size is not unexpected. Finally, the present study did not investigate the relationship between sailors TLs and their a) muscular endurance levels or b) skill level. Where a sailor with more muscle endurance or a higher skilled sailor may have a different internal load (considering that aerobic demand may be more important in lower skilled sailors [54]).

5.5 Practical Applications

Sailing is a self-paced environment sport. As a result, sailors participate with varying degrees of voluntary effort, although as WI increases more effort is required from the sailor to maintain control of the boat. It, therefore, seems possible that internal TLs imposed on Optimist sailors are subject to WI and duration of the training session. Ultimately, the environmental conditions are a substantial consideration which has an influence on the physical and physiological expenditure during Optimist sailing training. On this basis, coaches must monitor the TLs of Optimist sailors to assess and monitor how the sailors within a squad are adapting to the training.

Furthermore, the HR and subsequent TLs in different WIs suggest the need for specific training programs for competitive South African Optimist sailors. As well as possible adjustments when expecting certain conditions in future regattas, i.e. a session with a higher training intensity can be accomplished by either sailing in more wind or by increasing the duration of the session. While keeping in mind that the use of objective, HR-based methods are more reliable than subjective based methods (i.e. session-RPE) when determining the TLs of Optimist sailors. Consequently, we recommend that coaches and sports scientists use a combination of HR-based measures and session duration to monitor TLs of sailors. Ultimately, monitoring TLs of Optimist sailors will help make evidence-based decisions on appropriate loading schemes to plan training and eventually enhance the performance of the sailors.

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CHAPTER 6: CONCLUSION

The purpose of this dissertation was to further develop the scientific knowledge and understanding of high-level competitive Optimist sailing performance and training. This dissertation sought to develop a detailed analysis procedure to investigate and compare the performance indicators of high-level competitive Optimist sailors during a competition, as well as to provide information on absolute and relative training loads of competitive Optimist sailors in training sessions held in various wind intensities.

This final chapter provides an overview of the key findings within each of the studies, touching on the aims and objectives discussed in Chapter 2. Specifically, to determine the race performance indicators of high-level competitive Optimist sailing races during the IODA World Optimist Sailing Championships between 2014 and 2019 and create race performance profiles from these performance indicators. In addition, the contributions and limitations of this dissertation are discussed. Finally, reflections are provided to continue the research into the future and thus help to advance research and practice.

Investing in the performance and training of Optimist sailors is essential because the Optimist class is often referred to as the feeder class into many different formats of the sport; whether to sail around the world, compete in the prestigious America's Cup regatta compete or the Olympic Games. In the latter, for example, 63% of the 210 skippers who competed in the 2008 Olympic Games are former Optimist sailors, and 46% competed internationally in the Optimist class. Additionally, 85% of the medal-winning skippers began sailing in an Optimist dinghy (OptiWorld, 2008). In the 2012 Olympic Games, the number of former Optimist sailors increased with 79% of the 209 skippers and 59% having competed internationally. Furthermore, 20 of the 24 medallists sailed the Optimist dinghy (OptiWorld, 2012). Keeping this in mind, more research on the performance and training of sailors in the Optimist class is necessary since so many of the sailors, who learn to sail in this class, move on to greater achievements within the sport. Nevertheless, only a relatively small amount of published, scientific literature exists on the performance profiles, performance indicators and training loads of Optimist sailors.

With the help of technology, as well as emerging concepts within sports science, fundamental knowledge of athlete training processes and performance, are slowly evolving. These new methodologies for competition and training analyses are being applied in the training process and are continually improving the opportunities for researchers and professionals to observe sport from different perspectives (Cejuela-Anta & Esteve-Lanao, 2011). Furthermore, both internal load (Bernard et al*.,* 2009; Faria et al*.,* 2005) and external load (Cejela et al*.,* 2007; Vleck et al*.,* 2007) measures are being studied, and more in-depth knowledge of sport types and demands are being proposed. Importantly for professionals, the know-how and capability to accurately monitor athletes and their respective TLs are a necessary aspect in the process of athlete development and effectiveness (Bara Filho et al*.,* 2013).

6.1 Competitive Optimist Sailing Performance (Race Indicators and Profiles)

This dissertation showed that the performance of Optimist sailors during high-level regattas are inherently variable, even at the top level. For most sailors, the dynamic nature of the sport adds to the appeal of sailing in that the context of individual races is very rarely the same; which in turn challenges the fundamental tactics, skills, as well as the problem solving and decision-making processes of the sailors. Keeping this in mind, it seems logical that a better understanding of the race performance indicators relating to better sailing performance will help to analyse sailor performance during competition. Coaches can help improve a sailor's performance during races and subsequent outcome by providing more objective race analysis and feedback. The feedback should relate to what the sailor did and how they can improve.

Within any sporting performance, even the smallest change in performance may impact the outcome (Guellich et al., 2009). Therefore, this dissertation provides evidence of high-level competitive Optimist sailing racing performance through the identification of objective race performance indicators, determined based on coaches' feedback in conjunction with statistical analysis. The most appropriate performance indicators were used to build performance profiles based on the different race series (qualifying and finals) within a high-level Optimist regatta. The finals were then also split in accordance with the respective fleets. This was done in order to consider the quality of the opposition within the profile, which is imperative when compiling performance profiles. While it does not use the opponent quality rating methods suggested by O'Donoghue and colleagues (2011); it seemed to be the most appropriate method to compare performance indicators. Owning to the fact that Optimist sailors are not given an international ranking score, and involves multiple opponents as a mass start event. Also, considering the environmental conditions during each regatta, no significant differences for wind intensities were observed between the years from 2014 to 2018. Furthermore, the differences in environmental conditions were negated by reporting the performance indicators relating to race leader and overall race winner (i.e. time difference at each mark and VMG difference in each leg, respectively).

The performance indicators highlighted by this dissertation include the position at the respective marks, position change in all legs, VMG per leg, VMG difference from race winner per leg, time in each leg and overall, the time difference from the race leader at each mark, and distance sailed (per leg and overall). Once a performance profile has been established, the performance indicator values for the individual or team in question can be compared to previous performances of that individual or the performances of the relative population. For example, a coach can determine if their sailor's performance was lower or higher in relation to the typical performances of other sailors competing in similar high-level Optimist sailing races. Finally, it is necessary to relate performance indicator values to the relevant population's performances to compare the performances between sailors. An example of how the performance profile can be applied is shown in Figure 6.1. This information highlights that the sailor's performance was relatively similar when comparing the mean to the quartiles in position at each mark, with a slightly better position at mark 2. With respect to time difference, the sailor was closest to the leader at mark 1 and slowly dropped further back; this pattern is the same as the gold fleet profile. Lastly, this shows that the sailor's biggest weakness is seen in VMG difference in legs 2 and 3. Therefore, this should be the focus during training.

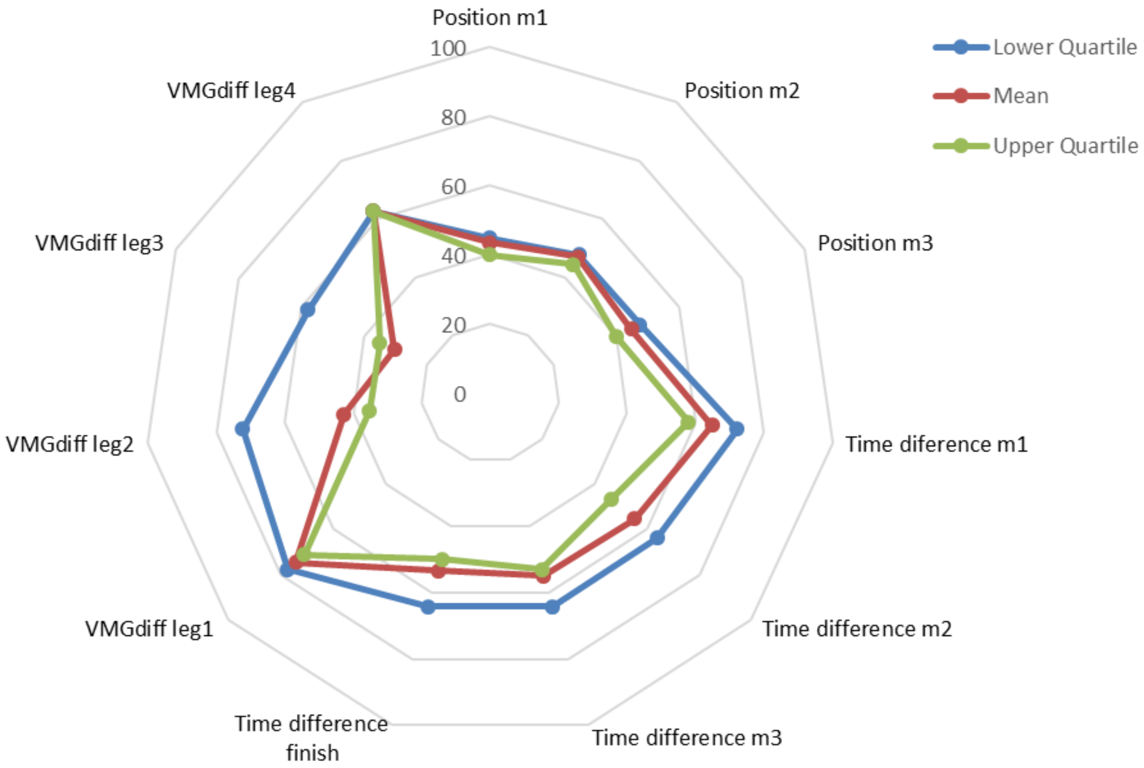

Figure 6.1. Radar chart to show an example of a performance profile for a sailor in the gold fleet.

This study has provided information on an actual competition without manipulation or interference of the racing condition. Confounding factors, such as being scored a DSQ (disqualification) or DNF (did not finish) may have an impact on final regatta standings. Nevertheless, the information is however valuable to coaches, sailors and sports scientists who are interested in the between-sailor variation and determination of performance in the various legs of the race. For example, the time difference from the race leader at each mark shows that the leaders gain time on the sailors that are further back in the race, as the race progresses. This may be because the leading boats can make the most of the clear air ahead of them, thus it is easier for them to maintain better VMG scores and they have more options to implement their strategy. While the strategic options of boats in the middle and back of the fleet are more limited in that their goal is to find a lane with clear air in order to maintain as good a VMG score as possible. Additionally, taking the gold fleet as an example, a coach can more accurately determine if their sailor is within the top group if he/she is within 122 seconds of the race leader at the second mark. As the sailors develop and learn more about the sport, both coaches and sailors could use the profiles built in this dissertation as a framework to guide an individuals' sailing development or that of a team.

Interestingly, the bronze fleet showed the most substantial differences between the sailors in the 90th percentile and those in the 10th percentile for total distance sailed and time difference at mark 1 and the finish compared to all the other fleets in the final series. This suggests that the sailors split into this fleet have the most significant skill level gap between one another. In contrast, the gold fleet has fewer positional changes within each leg which suggests that the sailors are more similarly matched in skill level compared to those in the other fleets. This highlights less variability between sailors during each race and suggests that it is more difficult for a sailor to improve their position after the first mark during the race. Thus, coaches need to train their sailors in as many random and variable training sessions as possible, which may also add to contextual interference and transfer skills from training to competitions. Consequently, the sailors refine their skills in as many contexts as possible and can therefore stay as consistent as possible during every race.

Although a useful performance indicator to compare performances between sailors, neither the time difference from the leader at a mark nor the position at each mark can assist in probing the within leg strategy adopted by each sailor. However, time taken to sail leg 4 was deemed a significant predictor of performance outcome in all profiles except for the gold fleet. This may suggest that sailors in these races can gain positions still if they can find a clear lane soon after rounding mark 3, and subsequently sail faster during this leg. This pattern is similar when considering the position change during the final leg in the silver and bronze fleets compared to the gold, i.e. one can see more positional changes (both gaining and losing) in leg 4.

The velocity made good (VMG) difference between a sailor and the race winner was highlighted by the coaches and the statistical analysis (statistically predictable in legs 1 and 3) as being valuable. Velocity made good is a measure of the actual speed towards a sailor's goal, i.e. the fastest speed over the shortest distance, in Optimist racing the goal is referred to as the next mark. Often, due to, for example, wind, waves or competitors, sailors cannot or choose not to sail a direct course towards the mark. When they are unable to, the sailor will aim to sail as close to a direct course while maintaining the highest possible speed. Therefore, a higher VMG score shows a faster and more direct course to the mark. The VMG difference from race winner was deemed significantly predictable during leg 3 for all fleets in the final series. Leg 3 is a downwind leg, as the sailor's race from mark 2 to mark 3 with the wind coming from behind them (Figure 2.4). The difference in VMG in this leg suggests that the sailors towards the front of the fleet can sail a more direct course towards the mark, as opposed to those in the middle who may tend to sail wider in order to find clean air and have space to surf the waves.

Throughout the dissertation, environmental conditions have been stressed as being hugely influential on sailing performance, as it interacts directly with strategical and tactical decisions within a race and ultimately affect the performance itself. Therefore, throughout the race, sailors should be aware of any changes in wind direction, angle and intensity in order to establish the wind patterns in each moment of the race. They are then using all their skills and experience to position their boat where it will gain the most significant advantage based on the expectations developed from the pattern. While it is not easy to assess this awareness and the outcome of the respective decisions made in each situation, distance sailed during each leg may be relevant. This can be compared to that of the race winner and in conjunction with observations and coaches experience, may possibly provide information relating to strategy. However, this should only be taken in the context of the race and by combining additional information. Furthermore, the position at each mark and race outcome are the critical performance indicators to see whether correct decisions were made in each leg or throughout the race.

It may be that factors such as fitness, racing experience and training history explain the difference in racing performance (Santos, Dias, Couceiro, Mendes, & Santos, 2016). In that, an increase in the wind intensity may lead to the performance being influenced more by the sailor's ability to tolerate the hiking position, as well as their skill in maintaining a flat boat. In contrast, during less wind, the sailors may require a better understanding of wind awareness and performance may be affected by mental fatigue. The sailors who qualified for the gold fleet are likely to have higher fitness levels, sailing skills and overall environmental awareness, which may explain better performances during the qualifying races (Table 3.5).

The determination of the performance profile in sailing has led to a better understanding of the various situational demands within the race and has the capability to provide information to a coach or sailor highlighting the point in the races where he or she might have lost or gained and thus what they need to improve on to better their performance. Furthermore, coaches can use the performance profile of the races as a reference when monitoring other competitive performances, as well as designing training programs. However, it is essential to note that while the performance profile developed in Chapter 3 provides objective information on some of the strategical elements within a race; only knowledge on average wind intensity and direction changes from each race is available. Unless observations were carried out in the situation (even then it is a simplified representation of the racecourse), it is challenging to conduct a post-race strategic and tactical analysis. Ultimately the performance profiles help in advancing the understanding of race behaviour with a view of improving future outcomes.

In conclusion, performance profiles can benefit coaches and sports scientists in that they can use the information to give more specific feedback to their sailor and highlight the sailor's strengths and weaknesses within the race compared to other sailors in the fleet. This can be used to develop training programs, as it can provide direction for training with which to work.

6.2 Training Loads

The scoping review provided valuable insight into published peer-reviewed studies which focused on training load and/or competition load monitoring methods in high-level competitive athletes participating in non-motorised water sports. The review highlighted that no studies, to date, have investigated training loads in high-level Optimist sailors. Additionally, no study has considered the difference in training loads of sailors in various wind intensities during an entire on-water session. However, the physical and physiological demands of upwind sailing on Optimist sailors have been previously estimated in a laboratory setting and during an on-water session (Lopez, Bourgois, Tam, Bruseghini & Capelli, 2016; Callewaert, Boone, Celie, De Clercq & Bourgois, 2014; Rodio, Madaffari, Olmeda, Petrone & Quattrini, 1999).

Sailors are required to sail various legs or angles to the wind during a competitive race. Therefore, it is essential to look at entire training sessions on the water compared to only sailing at one angle, such as the beating angle. Figures 2.1 and 2.4 show the different sailing angles and the typical course (in relation to the wind) for an Optimist race. Additionally, Pezzoli and Bellasio (2014) confirm that the wind has a very high impact on sailing, as well as race outcome. It seems logical, therefore, that a better understanding of the physical and physiological factors relating to Optimist sailing in various wind intensities can be used to direct training interventions and implement loading patterns for optimal adaptation. Thus, training sessions held in varying wind intensities were sought after to get an overall representation of the training loads of South African Optimist sailors during a typical sailing training session, as the wind conditions change.

The one observation was that energy expenditure was higher in strong wind intensities compared to light and medium, respectively. This confirms that a sailor is required to work harder while sailing in stronger wind intensities, as reported previously by Lopez and colleagues (2016), Callewaert and colleagues (2014) and Rodio and colleagues (1999), as this is also when sailors typically must start hiking. Even though the training load did not differ between moderate and strong wind intensities, there are differences between light and medium and light and strong wind. Consequently, the wind intensity should be considered as an external load for Optimist sailors during training and should be a factor in the monitoring process in order to ensure the sailor is adapting optimally to the training stimulus, as well as not becoming overloaded. This is important for coaches to be aware of since Optimist sailors have reported experiencing some degree of back pain during boat-related activities (rigging or pulling the boat from the water) and while sailing, mostly during the hiking position in strong or moderate conditions (Kostański, Frąckowiak & Pospieszna, 2019).

Interestingly, when considering methods to assess training load, according to the findings of the scoping review (Chapter 4), RPE measures are the most commonly used self-report assessment in surface water sports. However, in Chapter 5 it seemed that session-RPE and the training impulse (Banister's TRIMP) method may be used to quantify the training loads of young Optimist sailors. The use of the Banister TRIMP measure is suggested due to the subjective nature of the tool, in that the junior sailors may not yet have the ability to accurately self-assess perception of effort. Rodríguez-Marroyo and Antoñan (2015) supported this, as they also found that RPE may not be the most appropriate measure of internal load in youth soccer players. Furthermore, the reason for not including the revised measures (Lucía et al., 1999 and Manzi et al., 2009) in the protocol was to determine the best method for a coach to use and apply in their training program. As a result, lactate or gas exchange variables were not assessed. The addition of the Edwards SHRZ method was considered as this was deemed feasible and practical for coaches to use in practice. The nature of the HR zones are relatively easy to read and compare on a day to day basis. Yet, while practical and with some level of face validity, criterion validity for these methods have not yet been established. As a result, the Banister and Edwards TRIMP measures are often used in conjunction (e.g. Crawford et al., 2018, Alexiou & Coutts, 2008, Impellizerri et al., 2004). The conclusion, after comparing various measures, identifies Banister's TRIMP method as the recommended measure for internal load in South African Optimist sailors. However, it is noted that this method should be used with caution or in combination with the session-RPE method.

The only external training load variable included in the study was duration, as this is the most appropriate and applied measure to monitor the session. Distance and speed were not considered since the drills and training types can be different, and since the coach determined the sessions, these were difficult to standardise. For example, if one session focused on starting practice and another on straight-line speed, it seems evident that the sailor will cover more distance during the second session. Furthermore, the sailor on the boat is the determining factor of the boat speed and direction; if the sailor does not apply the appropriate amount of righting moment or they lack the skills to take advantage of the environmental conditions, their overall performance will be affected.

Therefore, internal load measures are more appropriate to assess the training load compared to external load measures, particularly during training. From the findings in Chapter 5 it is recommended that coaches and sports scientists use a combination of HR-based measures and session duration to monitor training loads of Optimist sailors. These findings are in agreement with the most commonly used methods to monitor training loads and competition loads in other high-level competitive non-motorised surface water sports (Chapter 4).

Chapter 5 showed that different environmental conditions pose different physical and physiological demands on the sailors; as such, we can assume that the same can be said during racing. However, racing also includes other additional uncontrollable factors; such as the quality and actions of the competitors within each race. To achieve success in sailing, sailors need to be able to cope with the variability of the environment, which has the potential of changing quickly and unpredictably, as well as being able to consider the actions of the other sailors. The changes in heart rate and subsequent training loads in different wind intensities from the study in Chapter 5 suggest the need for specific training programs in various wind intensities for Optimist sailors to better prepare them for the environmental conditions they may face during regattas.

In conclusion, quantifying the training loads of Optimist sailors (specifically related to wind intensities) provides insights into important aspects and considerations to help plan and direct training activities, in order to reduce the likelihood of injuries and ensure the athlete is adapting optimally. To achieve this, coaches should implement an athlete monitoring system to monitor the sailors training load using Banister's TRIMP method. A systematic process of training (involving various technical, tactical and strategic elements of the sport) evolving in the various environmental conditions, as well as adding pressure from various opponents at different skill levels is needed to improve tactical and strategic understanding. Thus, improving overall regatta consistency and creating a higher chance of achieving success.

6.3 This Dissertation's Contribution to the Sports Science Base of Knowledge

The scoping review in Chapter 4 is the first and only to investigate previous research on the methods used to monitoring training loads in non-motorised surface water sports. Chapter 4 highlights the gap in the literature and suggests a need to increase athlete monitoring in sports such as sailing. To date, no previous research was found to have investigated sailing race-specific performance indicators, nor does any published literature describe a race performance profile for Optimist sailing. Additionally, Chapter 5 is the first study to quantify the training loads of Optimist sailors and the effect of the wind intensities throughout an entire training session.

The performance profile developed in Chapter 4 can be used by coaches at the IODA Optimist World Championships as a reference when providing feedback to their sailor. They can determine the strengths and weaknesses of their sailor within a race and compare their performance to the opponents in the race or fleet. In addition, a coach can compare the performance of the same sailor in one race to subsequent races within the regatta or previous regattas and use this when planning the training program.

The information from this dissertation can be used to assist in the development of protocols and athlete monitoring strategies to assess the physiological and physical characteristics of Optimist sailors, monitor athletic performance, and improve training prescription of Optimist sailors.

While it is well known that environmental conditions influence the competitive performance of a sailor. The results of this dissertation highlight that the context within which the sailor finds themselves, specifically the wind intensities, seems to influence the physical demands of sailing. Where an increase in energy expenditure highlights a need for improved sport-specific muscular endurance of Optimist sailors. Therefore, training in sailing is necessary to develop muscular endurance and an ability to sustain the hiking position, so the sailor can perform tasks at a higher intensity compared to their opponents, thus, sustaining the level of intensity for longer. On-water training of Optimist the necessary adaptations and overall preparedness for performance during competition (Schneider, Hanakam, Wiewelhove, Döweling, Kellmann, Meyer, Pfeiffer, & Ferrauti, 2018).

6.4 Limitations and Future Studies

While the present study provides new information on performance indicators in competition and training loads in young Optimist sailors, there are several limitations which must be acknowledged. The data used in Chapter 3 did not give scope to describe the decisions made relating to the specific strategic and tactical manoeuvres. Due to the ever-changing environment and unpredictable context, it is close to impossible to successfully predict the best strategy or tactic to use in any one race situation. This being said, there is a lot to gain if one could develop individual race profiles indicting the finer details and manoeuvres within a race (such as number of tacks, which side of the course he/she sailed) and to compare these with the entire race; i.e. how the start (position on the line for example) impacts the first third of the beat and subsequent number of tacks or average velocity made good, and then the corresponding position once the sailor gets to the top mark. Nevertheless, through the development of PPs, this study provided a novel method for coaches to consider the performance of their sailor within high-level races.

The study in Chapter 3 is also limited in that it does not consider the actual wind direction and speed on the course at the time of the event. Thus, the description of the race area is limited. Future studies should, therefore, look at determining the actions of sailors during each leg, for example, the specific strategy adopted after the start and up the first windward leg.

A third limitation in this study is that no descriptive information about the sailors (aside from sex), was available. Future studies should consider collecting descriptive characteristics of the population, and determine if there is a relationship between fitness, years of experience of the sailor and how they compare based on the performance profile.

The conditions within which the sailors completed the training, Chapter 5, are not representative of all possible combinations of environmental conditions a sailor may be faced with during different regattas. The training only took place at sea; thus, the limitation is that all bodies of water (i.e. dams, lakes and rivers) were not considered. From a practical point, however, most large sailing regattas are held on the ocean in order to be sure there is enough space to lay the course.

Furthermore, a larger sample size and more recordings in Chapter 5 would increase the generalisation of the findings (even though the study was not underpowered). Still, the data was collected on a very particular and select population. The 12 participants who volunteered are from a total population of 31 sailors who fit the inclusion criteria (i.e. sailed in a National Championships within the last 12 months), and the group are representative of high-level competitive Optimist sailors. However, care should be taken when extending these findings to other groups, in that the data reflects the state of the sailors in this context and is therefore only directly applicable to sailors at the same or similar performance levels. In addition, data collection was conducted in an actual training environment, thus adding to the ecological validity. However, this may have contributed to further difficulty in that only 67 of a possible 114 (59%) of the data recordings were able to sync or be uploaded to the mobile device.

Additionally, the training loads observed in Chapter 5 are only representative of acute training loads. It was beyond the scope of this study to consider the chronic training loads of Optimist sailors. Future studies should look into longitudinal monitoring of Optimist sailors, and determine the acute, chronic ratio in high-level Optimist sailors.

Further monitoring of competitive sailors through internal and external TL methods during competition should be examined to determine a relationship between the training loads during training versus competition.

Quantifying time spent in hiking position during an Optimist sailing race and how this relates to environmental conditions, may provide further information into the physical demands and subsequent training stress of Optimist sailors.

To further enhance sailors training and exercise prescription, longitudinal studies investigating the responses and adaptations of sailing specific on-water training and land-based resistance training should be implemented.

6.5 Take Home Message

Therefore, in conclusion, the PIs identified in this dissertation (specifically time difference from the leader at each mark and VMG difference from race winner) provide objective descriptors of high-level competitive Optimist sailing racing performance and can be used to determine the aspects within a race where a sailor showed better or worse performance. The information a coach can gain by comparing a sailor's performance, based on the most relative performance indicators (i.e. position at each mark, time difference from the race leader and VMG difference from the race winner), to those of the performance profiles established in this dissertation may help the coaches to provide systematic and objective feedback to their sailors. In that, the purpose of training is to take an individual, i.e. an Optimist sailor, from their current skill and performance level to a point where they can improve and ultimately achieve some level of success. Also, to help them develop their tolerance to the various loads and subsequent exercise intensity during each wind category.

The results also highlight that more effort from the sailor is required during stronger wind intensities when compared to light wind intensity categories, however not significantly more than the moderate category. The TRIMP monitoring method is recommended for coaches who want to monitor their sailor's performance over time. Also, the physical and physiological outputs of Optimist sailors (heart rate and RPE scores) during training are dependent on the session duration (minutes) and wind intensity.

Thus, one of the motivations behind this dissertation is to determine what and how junior South African Optimist sailors are doing during training and competition in order share with coaches the need for athlete development and a structured, goal orientated training program.

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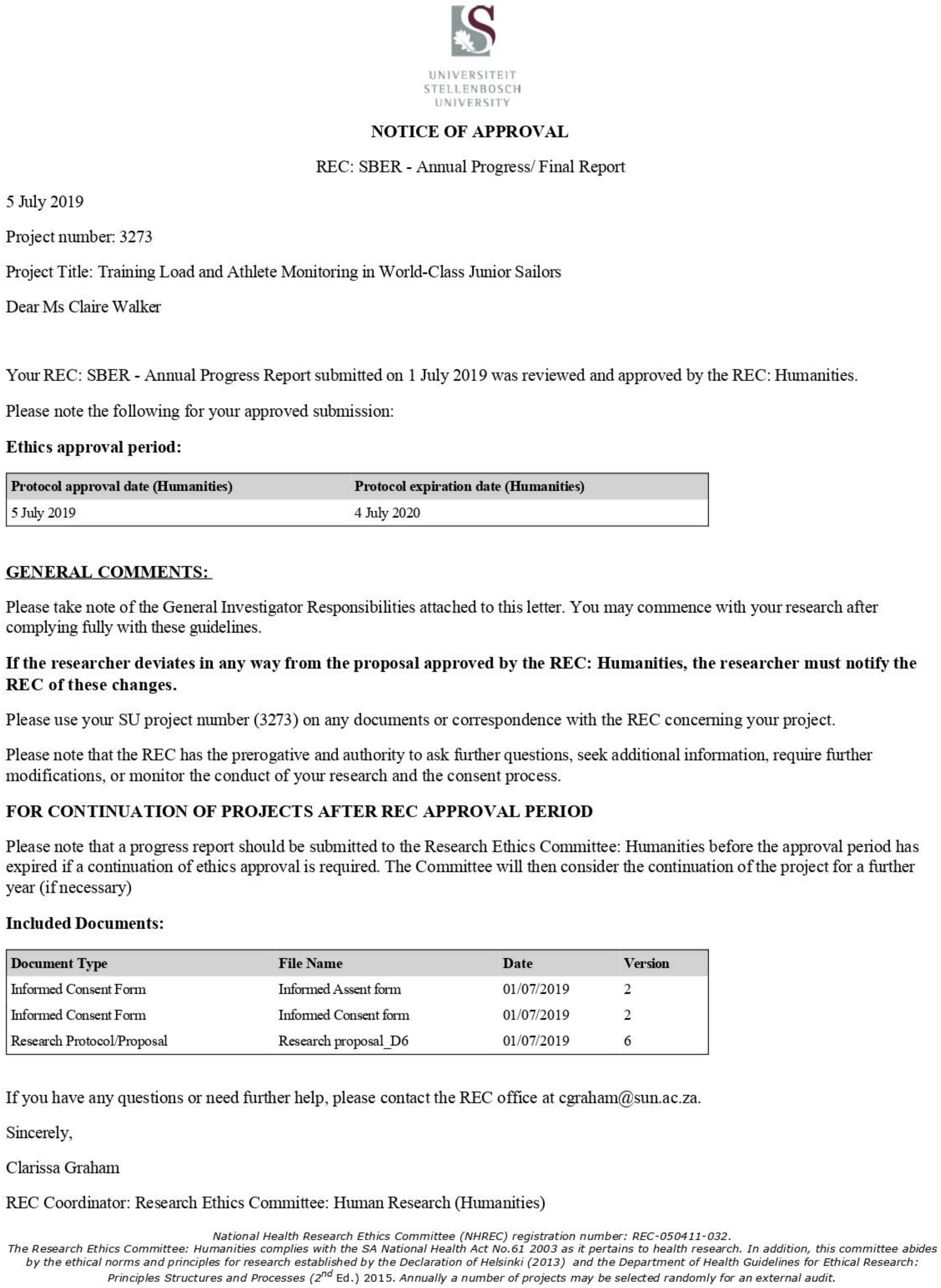
Addendum A: Ethical Approval



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NOTICE OF APPROVAL

REC: SBER - Annual Progress/ Final Report

5 July 2019

Project number: 3273

Project Title: Training Load and Athlete Monitoring in World-Class Junior Sailors

Dear Ms Claire Walker

Your REC: SBER - Annual Progress Report submitted on 1 July 2019 was reviewed and approved by the REC: Humanities.

Please note the following for your approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
5 July 2019	4 July 2020

GENERAL COMMENTS:

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number (3273) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Informed Consent Form	Informed Assent form	01/07/2019	2
Informed Consent Form	Informed Consent form	01/07/2019	2
Research Protocol/Proposal	Research proposal_D6	01/07/2019	6

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

National Health Research Ethics Committee (NHREC) registration number: REC-050411-032.
The Research Ethics Committee: Humanities complies with the SA National Health Act No.61 2003 as it pertains to health research. In addition, this committee abides by the ethical norms and principles for research established by the Declaration of Helsinki (2013) and the Department of Health Guidelines for Ethical Research: Principles Structures and Processes (2nd Ed.) 2015. Annually a number of projects may be selected randomly for an external audit.

Addendum B: Declaration by the Candidate

With regard to the whole dissertation, the nature and scope of my contribution were as follows:

Nature of contribution	Extent of contribution (%)
Study conception and design, funding and instrumentation, literature review, developed the search strategy for Article 1, participant recruitment, data collection, data interpretation, statistical analysis (Article 4), writer	75%

The following co-authors have contributed to [specify chapter or part of a chapter and page numbers in the dissertation]:

Name	e-mail address	Nature of contribution	Extent of contribution (%)
Dr Karen Welman	welman@sun.ac.za	Study design, drafting of article manuscripts, provided equipment for data collection (Article 3), statistical analysis (Article 2), data interpretation, provided feedback	20%
Prof Mike Lambert	mike.lambert@uct.ac.za	Third reviewer (Article 2), provided feedback (Articles 2 and 3)	5%

Signature of candidate: ……………………………………………………

Date: ………………………………………..

Declaration by co-authors:

The undersigned hereby confirm that

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to chapters 3 (pp) and 6 (pp),
2. no other authors contributed to this dissertation in its entirety besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in all parts of this dissertation.

Signature	Institutional affiliation	Date

Addendum C: Informed Consent Form

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
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STELLENBOSCH UNIVERSITY, SOUTH AFRICA
CONSENT TO PARTICIPATE IN RESEARCH

“TRAINING LOAD AND PERFORMANCE INDICATORS OF OPTIMIST SAILORS.”

Your child is asked to participate in a research study conducted by Claire Walker (MSc Sport Science), from the Department of Sport Science at Stellenbosch University. The results of this study will contribute to a research project which forms part of her PhD in Sport Science. Your child was selected as a possible participant in this study because they are a South African optimist sailor who has at least one year of racing experience.

1. PURPOSE OF THE STUDY

The purpose of the study is to monitor the training load of optimist sailors during on-water sailing training sessions; to make evidence-based decisions on the appropriate loading schemes during training. And, ultimately to enhance performance and reduce possible injures.

2. PROCEDURES

If your child volunteers to participate in this study, we would ask them to do the following things:

a) Your child will be asked to complete a general information questionnaire, which will supply us with information such as the age, gender, number of years sailing, competitive sailing history and any injuries of the sailors.
b) The participants will be required to wear a heart rate monitor during their on-water sailing training sessions. After every session, they will be asked to report their exertion during the whole session. The wind speed will be measured.
c) To record their training data for 6 weeks leading up to a regatta, such as the African Championships.

3. POTENTIAL RISKS AND DISCOMFORTS

The study holds no serious risks for your child, as they will be doing all their normal sailing training.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

Through this research we hope to provide insights into the training loads Optimist sailors are exposed to in varying environmental conditions (specifically wind intensity). To help the planning and development of Optimist training programmes for improvements in performance and a reduced injury risk. This study may also benefit the sailing community and other sporting codes which demand the same or similar training techniques.

5. PAYMENT FOR PARTICIPATION

Unfortunately, your child will not be paid to participate in this study. It is completely voluntary.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you and your child will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of ensuring that the data is saved on the researcher's laptop which is password protected. Any paper work will be locked in a cabinet in the Movement Laboratory, Department of Sport Science (Stellenbosch University). This Laboratory has limited access. The only persons who will have access to the information provided by your child will be the researcher and her study leader. If this research is published the identity of the participants will remain undisclosed. The participants' anonymity will be established by coding their names e.g. SAILOR_101. In the event that this research is published, no names will be mentioned and only average data will be reported.

7. PARTICIPATION AND WITHDRAWAL

Your child can choose whether to be in this study or not. If your child volunteers to be in this study, they may withdraw at any time without consequences of any kind. Your child may also refuse to answer any questions they don't want to answer and remain in the study. The investigator may withdraw them from this research if circumstances arise which warrant doing so. Your child may also choose to only participate in the light wind sessions without any consequences.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact the researcher Claire Walker cell: 084 299 5769 email: 16062876@sun.ac.za or her study leader Dr. K. Welman tell: 021 808 4733 email: welman@sun.ac.za.

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to ____ by ______________________________ in English and ____________________________________ in command of this language or it was satisfactorily translated to me. _______________________________ was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent that my child may participate in this study. I have been given a copy of this form.

____

Name of Subject/Participant

____

Name of Legal Representative (if applicable)

____ ______________________

Signature of Subject/Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ___________________________ and his/her representative ____________________________. He/she was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

____ ______________________

Signature of Investigator **Date**

Addendum D: Informed Assent Form

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STELLENBOSCH UNIVERSITY, SOUTH AFRICA
PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM

TITLE OF THE RESEARCH PROJECT: *"TRAINING LOAD AND PERFORMANCE INDICATORS OF OPTIMIST SAILORS."*

RESEARCHERS NAME(S): *Claire Walker*
EMAIL ADDRESS: *16062876@sun.ac.za*
CONTACT NUMBER: *084 299 5769*

What is RESEARCH?

Research is something we do to find new knowledge about the way things (and people/athletes) work. We use research projects or studies to help us find out more about helping people and improving their performance.

What is this research project all about?

This research project is about finding out if monitoring your training sessions can help to improve your performance and reduce any injuries you may get while sailing. We would like to identify if there is a difference in the amount of work you do during a training session in different wind strengths (light, medium and strong).

Why have I been invited to take part in this research project?

We are asking you to take part because you are a South African Optimist sailor who has competitive sailing racing experience and are currently training to compete in a future international or national regatta.

Who is doing the research?

I, Claire Walker, am doing this research as part of my PhD in Sport Science at Stellenbosch University, South Africa. I am doing this project under the supervision of Dr. K. Welman who is a lecturer at the Sport Science Department at Stellenbosch University, South Africa.

What will happen to me in this study?

You will be asked to wear a heart rate monitor during your normal training sessions. This will be to track your heart rate, which will hopefully tell me how much work you do in different wind intensities (light, medium, and strong).

Can anything bad happen to me?

The study holds no serious risks for you, as you will be following your normal training program structured by your sailing coach. You will not be responsible for any damage to the testing equipment. The researcher cannot be held responsible for any injury or event not directly related to the study. The information I collect for this study cannot be used to influence your selection into a team. If you feel like you want to talk to someone about your sailing performance we will refer you to a sport counsellor, Dr H Grobbelaar (+27 (0)21 808 4771 or +27 (0)21 808 4915).

Can anything good happen to me?

We hope to find that certain training sessions help with your performance. Also, to see how much work you do when on the boat during training and compare this between wind intensities. You will receive a written report with all your data and the averages of everyone who also took part at the end of the study.

Will anyone know I am in the study?

All your information and data will be kept private and only Claire and Dr. K. Welman will have access to it. The information and data will not be used for anything other than the results of this study.

Who can I talk to about the study? *If you have any questions or problems, contact Claire Walker cell: +27 84 299 5769 email: 16062876@sun.ac.za or Dr. K. Welman tell: +27 21 808 4733 email: welman@sun.ac.za.*

What if I do not want to do this?

You do not have to participate in this study, even with permission form your parents it is completely your own choice. There will be no consequences if you do not participate. If you agree to take part *and you decide you no longer want to participate, you may stop at any time without there being any consequences.*

Assent

Do you understand this research study and are you willing to take part in it?

YES NO

Has the researcher answered all your questions?

YES NO

Do you understand that you can pull out of the study at any time?

YES NO

Signature of Participant

Date

Addendum E: General Information Questionnaire

Name and Surname ______________________________

Date of birth ______________________________

Age ______________________________

Gender ______________________________

Weight ______________________________

How old were you when you started sailing?

____

How many years have you been sailing competitively/racing?

____

Which National and International regattas have you raced in since July 2018?

____

____

____

____

Addendum F: Instruction Document for Reporting RPE

RPE stands for Rate of Perceived Exertion or how hard you feel your body worked for the whole session. In research and training monitoring, we use the RPE scale to determine exercise intensity levels. It is a subjective measure, which means that it is something you decide for yourself.

The most important thing when you report your RPE is to make sure you are honest with yourself. This isn't a score about how you think you should feel after a session, or simply being a bad-ass ninja assassin crushing your way through each session. The goal is to be honest with yourself and how you are feeling, to make sure that the feedback we get is as accurate as possible.

Remember, only you and I will see what you write down, and that the score is not just about the wind conditions and what you did in the session but how you feel overall 30minutes after the session.

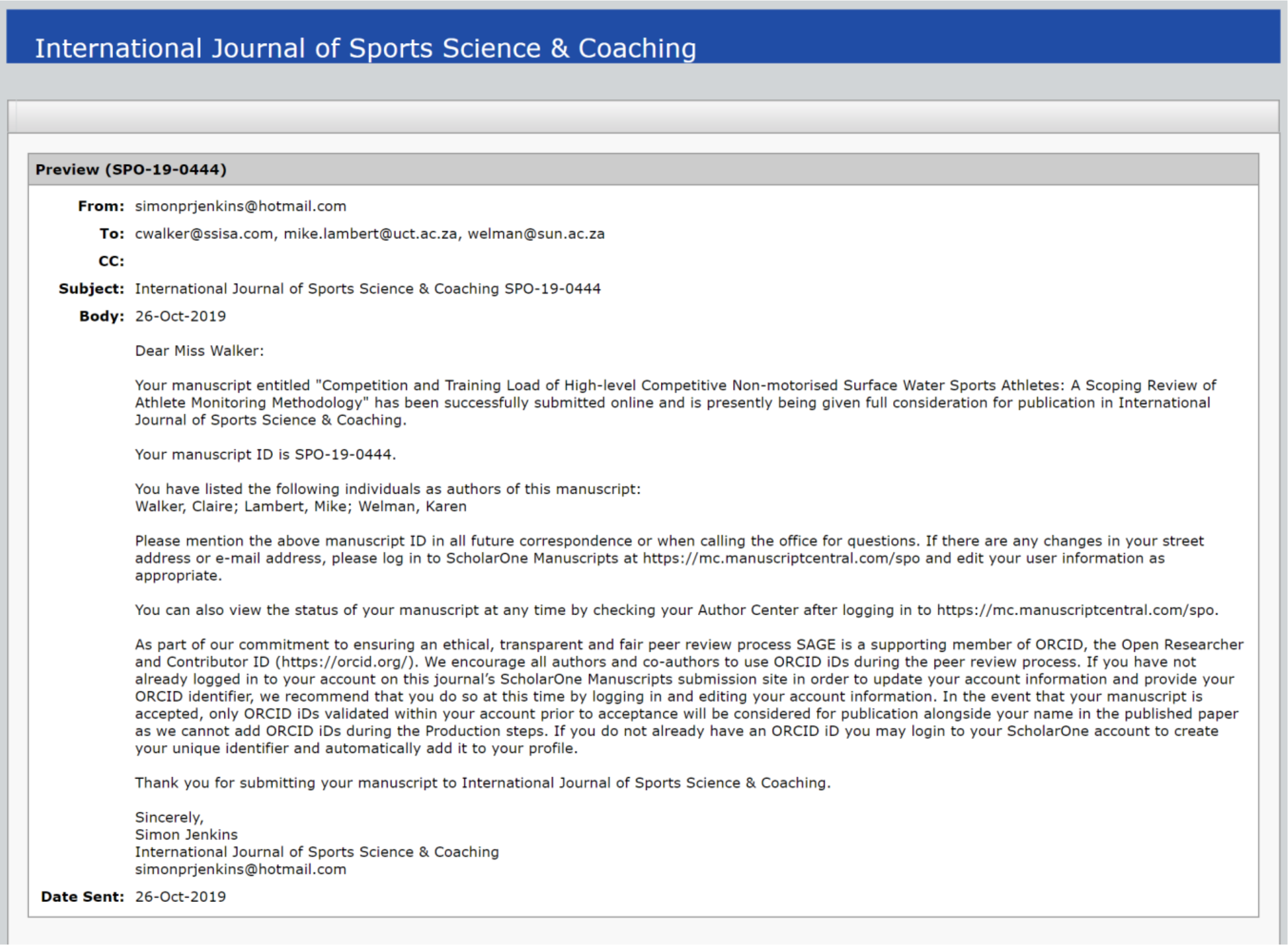
The RPE scale is from 0 to 10, with

- 0 being anything other than sleeping, such sitting and watching tv or riding in a car
- 2-3 is light exercise that you can keep doing for a long time
- 4-6 feeling like you can keep exercising like that for hours but are starting to breathe more heavily
- 7-8 starting to get uncomfortable (you can't hike all the time for example)
- 9 is difficult to maintain the exercise intensity
- 10 feeling like it is impossible to keep going for long

Rating	Descriptor
1	Really easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	-
7	Very hard
8	-
9	-
10	Maximal

After the session, ask yourself how tired you are feeling and decide which number is most like how your body worked during the whole session.

Addendum G: Manuscript Submission



International Journal of Sports Science & Coaching

Preview (SPO-19-0444)

From: simonprjenkins@hotmail.com

To: cwalker@ssisa.com, mike.lambert@uct.ac.za, welman@sun.ac.za

CC:

Subject: International Journal of Sports Science & Coaching SPO-19-0444

Body: 26-Oct-2019

Dear Miss Walker:

Your manuscript entitled "Competition and Training Load of High-level Competitive Non-motorised Surface Water Sports Athletes: A Scoping Review of Athlete Monitoring Methodology" has been successfully submitted online and is presently being given full consideration for publication in International Journal of Sports Science & Coaching.

Your manuscript ID is SPO-19-0444.

You have listed the following individuals as authors of this manuscript:
Walker, Claire; Lambert, Mike; Welman, Karen

Please mention the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your street address or e-mail address, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/spo and edit your user information as appropriate.

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Thank you for submitting your manuscript to International Journal of Sports Science & Coaching.

Sincerely,
Simon Jenkins
International Journal of Sports Science & Coaching
simonprjenkins@hotmail.com

Date Sent: 26-Oct-2019

Addendum H: Optimist Speed Chart for Race Committee Officials

IODA Race Management Policies V2 (2019).

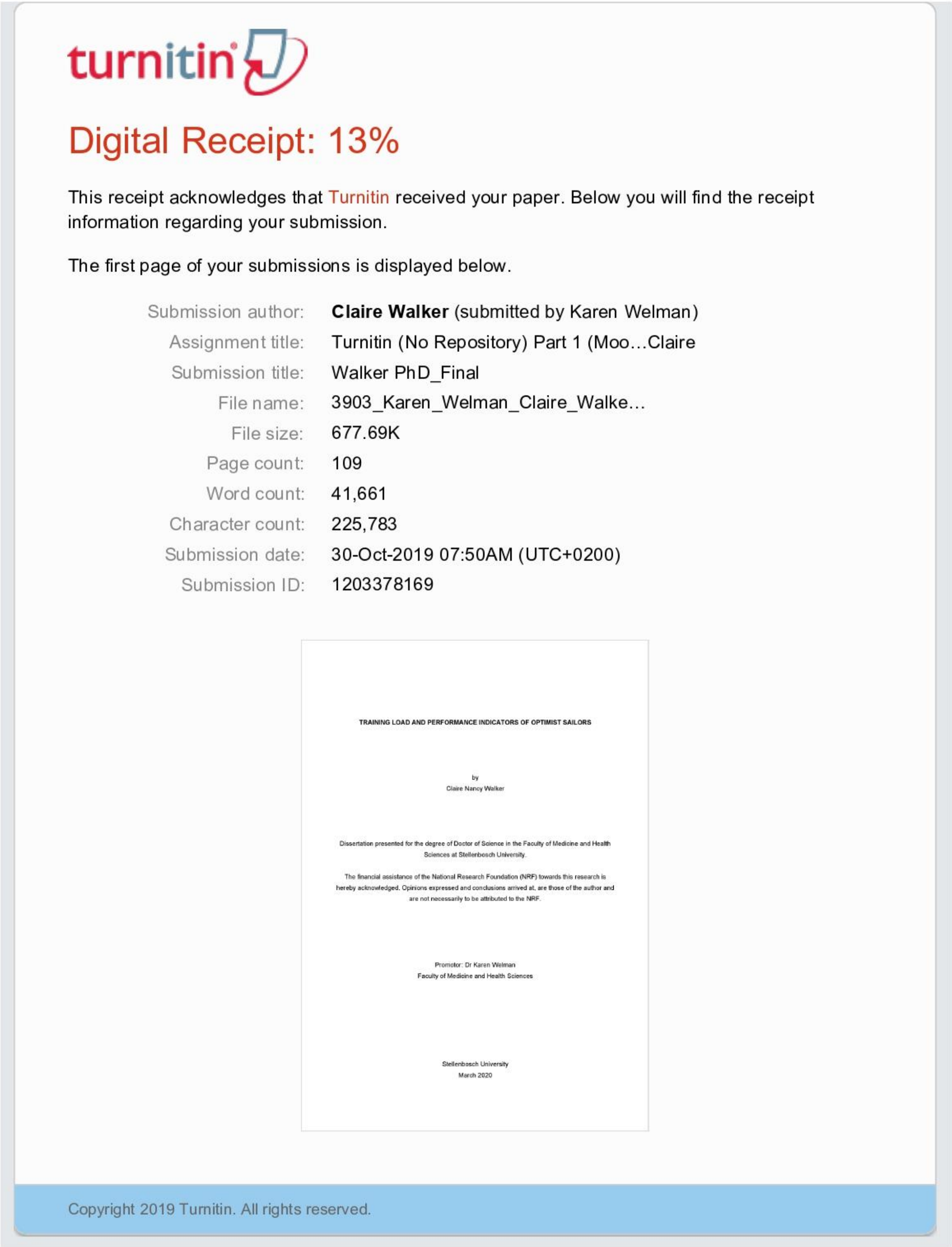
SAILING COURSE TIMES

OPTIMIST STANDARD COURSE

Target Time 50 minutes

Wind Range	5 - 8 Knots				8 - 12 Knots				12 - 15 Knots				15+ Knots			
Upwind Speed	32 mins/mile	Up Time (mins)	Down Time (mins)	Reach Time (mins)	26 mins/mile	Up Time (mins)	Down Time (mins)	Reach Time (mins)	24 mins/mile	Up Time (mins)	Down Time (mins)	Reach Time (mins)	26 mins/mile	Up Time (mins)	Down Time (mins)	Reach Time (mins)
Run Speed	18 mins/mile				15 mins/mile				14 mins/mile				13 mins/mile			
Reach Speed	20 mins/mile				17 mins/mile				15 mins/mile				14 mins/mile			
Leg Length Nautical Miles	Standard course				Standard course				Standard course				Standard course			
0.3	30.6	9.6	5.4	6.0	25.2	7.8	4.5	5.1	23.1	7.2	4.2	4.5	23.7	7.8	3.9	4.2
0.35	35.7	11.2	6.3	7.0	29.4	9.1	5.3	6.0	27.0	8.4	4.9	5.3	27.7	9.1	4.6	4.9
0.4	40.8	12.8	7.2	8.0	33.6	10.4	6.0	6.8	30.8	9.6	5.6	6.0	31.6	10.4	5.2	5.6
0.45	45.9	14.4	8.1	9.0	37.8	11.7	6.8	7.7	34.7	10.8	6.3	6.8	35.6	11.7	5.9	6.3
0.5	51.0	16.0	9.0	10.0	42.0	13.0	7.5	8.5	38.5	12.0	7.0	7.5	39.5	13.0	6.5	7.0
0.55	56.1	17.6	9.9	11.0	46.2	14.3	8.3	9.4	42.4	13.2	7.7	8.3	43.5	14.3	7.2	7.7
0.6	61.2	19.2	10.8	12.0	50.4	15.6	9.0	10.2	46.2	14.4	8.4	9.0	47.4	15.6	7.8	8.4
0.65	66.3	20.8	11.7	13.0	54.6	16.9	9.8	11.1	50.1	15.6	9.1	9.8	51.4	16.9	8.5	9.1
0.7	71.4	22.4	12.6	14.0	58.8	18.2	10.5	11.9	53.9	16.8	9.8	10.5	55.3	18.2	9.1	9.8

Addendum I: Turnitin Report



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TRAINING LOAD AND PERFORMANCE INDICATORS OF OPTIMIST SAILORS

by
Claire Nancy Walker

Dissertation presented for the degree of Doctor of Science in the Faculty of Medicine and Health Sciences at Stellenbosch University.

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

Promotor: Dr Karen Welman
Faculty of Medicine and Health Sciences

Stellenbosch University
March 2020