Training load and athlete well-being in university female hockey players during a congested tournament

by

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a dissertation submitted in partial fulfilment of the requirements for the degree

MSc (Sports Science)

in the Division of Biokinetics and Sport Science

Department of Physiology

Faculty of Health Sciences

University of Pretoria

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2020

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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I declare that this dissertation is my own original work. Where secondary material is used, this has been carefully acknowledged and referenced in accordance with university requirements.

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ACKNOWLEDGEMENTS

I wish to extend my deepest appreciation to the following people without whose assistance and support this dissertation would have been impossible:

Dr Francè Rossouw, my supervisor, Department of Physiology, University of Pretoria: for her guidance, support and persistence in striving to get the best out of me as a student. Your expertise has been invaluable throughout this journey.

Mr James R Clark, my co-supervisor, Department of Physiology, University of Pretoria: for his assistance and willingness to share his valuable insight and provide support throughout this journey.

Division of Biokinetics and Sport Science, Department of Physiology, University of Pretoria: for providing the platform and academic resources for data collection in this study.

Sport, Exercise Medicine and Lifestyle Institute (SEMLI), University of Pretoria: for making available the facilities, equipment and Smartabase application to complete the study.

TuksSport and the TuksHockey club: for proving the structures and support for data collection.

Ms Tanita Cronje, Department of Statistics, University of Pretoria: for her valuable statistical advice and assistance with data analysis in this study.

To my family, Howard, Bronwyn, Gareth and Ashleigh Swan, thank you for support and willingness to be there for me throughout the process. You have shown me that no matter how tough times are, we can always get through them together.

The TuksHockey women's team for their willingness to participate in scientific research and add value to the South African hockey context.

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List of symbols and abbreviations

AU	arbitrary units
cm	centimetre(s)
CR	category ratio(s)
d	day(s)
DOMS	delayed-onset muscle soreness
et al.	and others
FIH	International Hockey Federation
GPS	global positioning system
g	gram(s)
h	hour(s)
HID	high intensity running distance
HR	heart rate
Hz	Hertz
i.e.	Id est
kg	kilogram(s)
$km.h^{-1}$	kilometres per hour
min	minute(s)
m	metre(s)
$m \cdot min^{-1}$	metres per minute
OTS	overtraining syndrome
SD	standard deviation
SEMLI	Sport, Exercise Medicine & Lifestyle Institute
TD	total running distance
UP	University of Pretoria
USSA	University Sport South Africa
y	year(s)
<	less than
>	larger than
±	plus minus

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Abstract

Title: Training load and athlete well-being in university female hockey players during a congested tournament

The monitoring of athlete workload is common practice within field-based team sports. Athlete monitoring is performed using both objective and subjective monitoring tools. Results from previous research investigating the relationships between measures of well-being and external workload in the form of match running performance, have been described as uncertain. A lack of research exists in quantifying the workload and well-being of student-athletes during congested periods of competition. Thus, the purpose of this study was to investigate and quantify the match running performance and well-being demands experienced, and understand the relationships between subjective and objective workload measures, in female student field hockey players during a congested period of competition.

The cohort investigated comprised 16 female student field hockey players (age: 20 ± 2 y) in a South African university team. The reporting of player well-being (fatigue, soreness, stress, energy levels, motivation, sleep quality, total well-being), and session rating of perceived exertion (sRPE) was performed using a smartphone application before and after match-play on each of the five days of the tournament, and on Day 6. External workload variables during match play were recorded using global positioning system (GPS) wearable technology (Polar Electro Oy, Kempele City, Finland). Descriptive statistics, expressed as median and interquartile range (IQR), were calculated for all outcome variables for each day, and overall. To determine the strength and significance of the relationships between the three categories of variables (well-being, internal workload and external workload), Pearson correlation coefficients and Spearman rank order correlation coefficients were calculated.

Overall match running performance scores for the competition included total distance (TD): 4,545 (3,834 - 5,305) m; average work rate: 116.8 (104.0 - 123.1) $m \cdot min^{-1}$; high intensity (>16 $km \cdot h^{-1}$) running distance (HID): 383 (257 - 538) m; and average high-intensity work rate: 11.1 (5.8 - 14.9) $m \cdot min^{-1}$. Overall player total well-being, internal workload (sRPE x player match time) and match time for the competition were 15.0

(13.0 - 18.0) AU, 287 (214 – 355) AU and 39.1 (32.9 - 47.6) min, respectively. External workload demands were lower than those reported in previous literature on elite female field hockey players. Even though scores in well-being in the current study demonstrated trends of increasing (worsening) over the duration of the competition, changes observed were trivial to small and non-significant. Analysis showed inconsistent and non-significant relationships between pre-game well-being and same-day match external workload. Furthermore, several significant ($p < 0.05$) relationships were demonstrated between external workload on the preceding day to well-being subscales on the subsequent day.

Findings suggest that subscales (stress, fatigue, soreness) rather than total well-being score may be a more sensitive reflection of the workload experienced during congested tournaments. Furthermore, the current study supports the use of the sRPE-method of internal workload monitoring during field hockey match-play as a non-invasive and cost-effective means of reflecting player external workload. Prior to returning to sports training or academic commitments, due to the physical and psychosocial demands of such competitions, recovery should be prioritised within a student-athlete population.

Key words: Congested competition, external workload, field hockey, GPS, internal workload, team sport, well-being.

Chapter 1

Scope and Intent

1.1 Introduction

Field hockey is a dynamic team-based sport, incorporating technical, tactical as well physical elements (McGuinness, McMahon, Malone, Kenna, Passmore & Collins, 2018). The sport is played internationally at different levels ranging from amateur to elite (Jennings, Cormack, Coutts & Aughey, 2012). Field hockey is classified as a high-intensity sport which is intermittent in nature (McMahon & Kennedy, 2017). There exists a considerable lack of available literature on the physical and psychological demands on female hockey players during congested tournaments, especially after rule changes employed by the International Hockey Federation (FIH) in 2015 which included a format change from two halves of 35 min to four quarters of 15 min, as well as introduction of rolling substitutions (McMahon & Kennedy, 2017).

Across all levels of participation, field hockey tournaments commonly comprise of multiple matches scheduled over constrained time periods and are congested in nature (Jennings et al. 2012; Ihsan, Tan, Sahrom, Choo, Chia & Aziz, 2017; Lockie, Moreno, Lazar, Orjalo, Giuliano, Risso, Davis, Crelling, Lockwood & Jalilvand, 2016; McGuinness, Malone, Petrakos & Collins, 2017; McGuinness et al. 2018). This congestion of fixtures thus requires optimal physical preparation and recovery protocols (Jennings et al. 2012). In comparison to international-level hockey tournaments, university field hockey competitions such as the annual University Sport South Africa (USSA) inter-university tournament do not include rest or recovery days (Jennings et al. 2012; Ihsan et al. 2017; McGuinness et al. 2018). These unique tournament constraints lead to potential acute elevations in workload which may progress student-athletes into adverse states of well-being and fatigue (Soligard, Schwellnus, Alonso, Bahr, Clarsen, Dijkstra, Gabbett, Gleeson, Hägglund, Hutchinson, Janse van Rensburg, Khan, Meeusen, Orchard, Pluim, Raftery, Budgett & Engebretsen, 2016). Furthermore, it is well established that sudden acute increases in workload have been associated with an increased risk of injury and illness (Hulin, Gabbett, Lawson, Caputi & Samson, 2016; Drew & Finch, 2016; Soligard et al. 2016; Bourdon, Cardinale, Murray, Gastin, Kellmann, Varley, Gabbett, Coutts, Burgess, Gregson & Cable, 2017; Thornton, Delaney, Duthie, Scott, Chivers, Sanctuary & Dascombe, 2016).

Athlete monitoring systems are widely used as a means of assessing athlete and player responses to and coping with training and competition demands (Thornton, Delaney, Duthie & Dascombe, 2019). Athlete monitoring systems aim to minimise the risk of illness and injury and improve decision making processes for match performance (Thornton et al. 2019).

The use of both subjective and objective measures of athlete demands is recommended for effective athlete monitoring (Saw, Main & Gastin, 2015; Jones, Griffiths & Mellalieu, 2016; Soligard et al. 2016). Common forms of subjective athlete monitoring incorporate scores for total well-being and/or well-being subscales (Taylor, Chapman, Cronin, Newton & Gill, 2012; Saw et al. 2015; Thorpe, Atkinson, Drust & Gregson, 2017; Wellman, Coad, Flynn, Siam & McLellan, 2019) and perceptual-based methods of workload (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal & Dodge, 2001; Haddad, Stylianides, Djaoui, Dellal & Chamari, 2017; McLaren, Macpherson, Coutts, Hurst & Spears, 2017). In recent years the use of global positioning system (GPS) wearable technology as an objective measurement tool for external workload in team sports has gained significant popularity (Ihsan et al. 2017; Malone, Lovell, Varley & Coutts, 2017; McGuinness, Malone, Petrakos & Collins, 2017; McGuinness et al. 2018; Wellman et al. 2019). Common GPS measurements used to quantify external workload within team sports are total distance (TD) covered (Torreño, Izquierdo, Coutts, de Villarreal, Clemente, & Arrones, 2016; Ihsan et al. 2017; Malone et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018; Wellman et al. 2019), work-rate (Torreño et al. 2016; Ihsan et al. 2017; McGuinness et al. 2018), and high-intensity running distance (Ihsan et al. 2017; McGuinness et al. 2018).

It is suggested that the most effective approaches for athlete monitoring make use of subjective and objective measures of workload applied in conjunction with each other (Saw et al. 2015; Jones et al. 2016; Soligard et al. 2016). Although subjective and objective forms of workload measurement are valuable in athlete monitoring practice, the relationships that may exist between these sets of variables under the unique demands of competition are unclear (Lockie et al. 2016; Malone et al. 2017; Wellman et al. 2019).

Currently there is a lack of scientific literature on female field hockey players in general, and female student-athlete field hockey players specifically, that quantifies the performance demands of congested tournaments. Furthermore, previous research conducted on elite international-level female field hockey players during congested competition periods has not investigated the relationships between objective and subjective workload measures (McMahon & Kennedy, 2017; McGuinness et al. 2018).

1.2 Problem statement

Over recent years it is evident that maintaining or achieving optimal athletic performance through the utilisation of athlete monitoring approaches is a high priority across many sporting codes. Reasons include the high financial rewards of winning, time and financial cost of injury or illness, and concern for the well-being of athletes (Soligard et al. 2016). As a result, there has been a rapid increase in the number of monitoring tools and approaches available for sports practitioners to implement (Taylor et al. 2012; Saw et al. 2015). In sports such as field hockey, uncertainty exists with regards to the workload demands athletes across various playing levels are exposed to during congested periods of competition In addition there is a considerable lack in literature available in athlete monitoring application taking a multifactorial approach (a combination of external workload, internal workload and well-being) , especially in the female population.

Participation in sport at a university-level exposes student-athletes to unique demands specific to competition (Ihsan et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018) and academic commitments (Surujlal, Van Zyl & Nolan, 2013; Huml, Svensson & Hancock, 2017). The inability to maintain a healthy balance between both sport and academics, as well as personal lifestyle may lead to detrimental effects in one or more of these spheres (Surujlal et al. 2013; Huml et al. 2017). During competitions, small changes either on or off the field has the chance to have detrimental influence on performance and inevitably on results. Gaining insights into the demands that players are exposed to during congested periods of competition, supports a more methodical approach to be implemented when preparing for such tournaments.

The purpose of this study was to quantify running performance (external workload) demands in a team of female student field hockey players during a congested competitive tournament, and to investigate the associations between subjective (well-being and internal workload) and objective (external workload) measures of performance demands and responses. Furthermore, changes over the course of the tournament were investigated, and relationships between selected predictive (e.g. well-being) and outcome (e.g. running performance) variables explored.

1.3 Aim and objectives

The aim of this study was to quantify and explore the associations between athlete well-being, internal workload and external workload in a team of female student hockey players during a five-day congested competitive tournament, and to investigate whether changes occurred in the variables during the course of the tournament.

The objectives of this research study were:

- Quantify athlete well-being using a self-report questionnaire, and internal workload using the session rating of perceived exertion (sRPE) method, in a team of female student hockey players, daily and in total, during a congested competitive tournament.
- Quantify athlete external workload in the form of GPS-measured match running performance in a team of female student hockey players, daily and in total, during a congested competitive tournament.
- Determine the strength of the relationships between athlete well-being, internal workload and external workload in a group of female student hockey players, daily and in total, during a congested competitive tournament.
- Determine the effect that variables of self-reported athlete well-being have on match running performance, and determine the strength of the effect that match running performance may have on athlete well-being (i.e. total well-being and six subscales of well-being) reported on the subsequent day, in a group of female student hockey players during a congested competitive tournament.

1.4 Outline of the dissertation

The remainder of the dissertation consists of:

- Chapter 2: A literature review relating to the research topic, which is validated using various information and literature sources. This was then further refined to the specific detail of the current research project.
- Chapter 3: Description of the research methodology (sample, setting, instruments, and statistical analysis), procedures and ethical consideration of this study.
- Chapter 4: Reporting of the research results (sample demographics, physical performance tests scores, well-being scores and correlation analysis) specified in the current research study.
- Chapter 5: A discussion of the research results, along with the strengths and limitations of the study, conclusions and recommendations for future research.

Chapter 2

Literature Review

2.1 Athlete monitoring in team sports

It is well known that sport has changed considerably in recent decades specifically in professionalisation, competitive season lengths, and the increased number of high-priority events within sporting calendars (Surujlal et al. 2013; Soligard et al. 2016). This has led to added stress and demand placed on athletes, ranging from development to international levels of participation (Surujlal et al. 2013; Soligard et al. 2016).

In sport science it is common practice to implement athlete monitoring procedures to assess a wide scope of athlete responses (Jones et al. 2016; Soligard et al. 2016). These responses may be to both training and competition (Jones et al. 2016). Fluctuations in athletes' responses to training and competition need to be monitored to assess their state of health and preparedness to perform (Halson, 2014; Soligard et al. 2016). Monitoring these responses aims to improve athlete preparation and reduce the risk of injury, illness and overtraining (Halson, 2014; Bourdon et al. 2017). Research on European football reports that teams with lower injury incidence rates and higher levels of player availability demonstrate greater team success (Drew & Finch, 2016). Reasons reported for using athlete monitoring in high-performance programs include reducing the risk of both injury and the development of overtraining syndrome (OTS), assessing the effectiveness of the training regime, and sustaining performance levels (Taylor et al. 2012).

In parallel with the increase in professionalisation of sport in recent decades there has been an increase in sports participation across all levels of sport. This trend can also be observed at university level (Surujlal et al. 2013; Soligard et al. 2016). The student-athlete population is unique, as individuals are often required to compete across multiple levels (club, university, representative) while facing several challenges covering sport, academics and personal aspects (Surujlal et al. 2013). Not only do student-athletes compete within their respective sport, but considerable competition exists for academic programme admission between students (Surujlal et al. 2013). Upholding well-balanced lifestyles and managing various personal relationships with family, friends and academic peers speak to these unique demands (Surujlal et al. 2013; Huml et al. 2017).

At the University of Pretoria (UP), student-athletes may represent their institution in competitions ranging from University Sport South Africa (USSA) sanctioned events to provincial and national level representation. Sports competitions at a university level are unique in comparison to that at international level (Lockie et al. 2016). Reasons for this are highly congested seasonal and tournament scheduling as a result of university academic and holiday schedules (Lockie et al. 2016). An example of this scheduling for student-athletes is the annual USSA field hockey tournament which requires five matches to be played over five consecutive days. In comparison, an international level field hockey tournament typically spans on average 10 days with a maximum of seven matches in this period (McGuinness et al. 2018).

2.1.1 Well-being

Competitive athletes participating in sport, striving for high levels of achievement, often find themselves impacted by significant physical and psychological stressors (Linqvist, 2011). These physical and psychological challenges could be as a result of either personal or perceived expectations experienced by the athletes, which may lead to positive or detrimental well-being and health outcomes (Linqvist, 2011; Giles, Fletcher, Arnold, Ashfield & Harrison, 2020). Currently there is no consensus on a universal definition for well-being, creating confusion on how research should be conducted, as well as the conclusions that can be drawn from literature (Linqvist, 2011, Giles et al. 2020). Various sources investigating well-being in sport deem it a holistic term that encapsulates mental, social, and physical well-being (Giles et al. 2020). The term may imply an athlete's perception of general well-being, including feelings of wellness, physical fatigue, readiness to perform, and overall life satisfaction (Surujlal et al. 2013; Soligard et al. 2016; Malone, Owen, Newton, Mendes, Tiernan, Hughes & Collins, 2018). It is common perception among sport science support staff that a high level of well-being is required for athletes to perform successfully within competitive environments (Linqvist, 2011).

Commonly used validated questionnaire tools for well-being monitoring are the Profile of Mood States (POMS), Daily Analysis of Life Demands (DALDA), Hooper index, and the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) (Turner, 2018). However, in daily practice short, customised single-item questionnaires are often used, thereby suiting the needs of the coaching staff for low cost, time-efficiency, athlete compliance and convention (Taylor et al. 2012; Saw et al. 2015; Gallo, Cormack, Gabbett & Lorenzen, 2016; Thorpe et al. 2017; Wellman et al. 2019; Duignan, Doherty, Caufield & Blake, 2020). These athlete self-report measures may consist of a single question to assess a dimension/subscale of well-being (Duignan et al. 2020). Subscales which are regularly included when evaluating athlete well-being are fatigue, soreness, stress, and sleep quality (Saw et al. 2015; Soligard et al. 2016, Ihsan et al. 2017; Wellman et al. 2019; Duignan et al. 2020). In their review of available literature, Maine and Grove (2009) proposed six key well-being factors (depression, vigour, physical symptoms, sleep disturbances, stress and fatigue) that may be monitored in athletes. The authors proposed that these six well-being factors could be measured in a multi-component training distress scale (MTDS) that may require athletes to respond to customised statements/phrases (Main & Grove, 2009). For the purpose of the current study, the single-item well-being questionnaire used was adapted from Main and Grove (2009) and Grove, Main, Partridge, Bishop, Russell, Shepherdson and Ferguson (2014), and included scores for total well-being, fatigue, soreness, stress, motivation, energy levels and sleep quality (Appendix A).

Well-being is often scored through the use of a rating on a Likert scale with responses ranging from low to high, or from unfavourable to favourable, for various well-being subscales (Wellman et al. 2019). Questionnaire instructions commonly state that the athletes should rate each well-being subscale on how they perceive their state to be at that moment in time (Main & Grove, 2009; Grove et al. 2014). The total or overall well-being status/score is made up by summing and/or averaging scores for the well-being subscales (Clemente, Teles Bredt, Moreira Praça, Duarte & Mendes, 2020; Duignan et al. 2020). In the digital age, well-being questionnaires are often filled out using smartphone applications which have been found to reduce external influences such as sharing of responses between players (Clemente et al. 2020). Even though the single-item subscales that may be of use in monitoring well-being responses to training load in team sport athletes have been identified (Main & Grove, 2009; Grove et al. 2014; Saw et al. 2015) and remain appropriate for immediate, daily feedback to the support staff (Duignan et al. 2020), the relationship between these measures and athlete workload remains a subject of debate (Saw et al. 2015; Duignan et al. 2020).

A limited number of studies have documented athlete well-being associations with workload during competition. To the knowledge of the researcher only seven original research studies to date have documented athlete well-being and its associations with workload in team sport athletes during high-load match-play involving a congested fixture schedule (Ihsan et al. 2017; McGuinness et al. 2018; Rabbani et al. 2018) and match-play (Thorpe, Strudwick, Buchheit, Atkinson, Drust & Gregson, 2015; Fessi & Moalla 2018; Malone et al. 2018; Wellman et al. 2019). However, a more substantial body of research exist on well-being monitoring during various phases of training (Saw et al. 2015; Drew & Finch 2016; Fessi, Nouira, Dellal, Owen, Elloumi & Moalla, 2016; Gallo et al. 2016; Moalla, Fessi, Farhat, Nouira, Wong & Dupont, 2016; Clemente, Mendes, Nikolaidis, Calvete, Carriço & Owen, 2017; Mendes et al. 2018; Wellman et al. 2019; Campbell et al. 2020; Duignan et al. 2020).

During periods of training and pre-competition preparation, training volume and intensity are manipulated toward progressively higher workloads (Fessi et al. 2016). When investigating the differences in monotony, strain, and athlete well-being between training periods in professional soccer players, Fessi et al. (2016) reported significantly higher (adverse) states of well-being during the pre-season compared to the in-season period. The findings of worsened well-being during the pre-season training period were associated with the a considerably higher training workload (Fessi et al. 2016).

A recent study by Campbell, Stewart, Sirotic & Minett, (2020) investigated the relationship between exercise intensity dose and well-being scores over various time frames (pre-, post- and 24 h post-session) in amateur male team sport athletes during a scaled (low-, moderate- and high-dose) 90-min simulated soccer match shuttle run protocol. Notable findings were that participants reported worse scores of total well-being, fatigue, soreness, readiness to train, and mood after the high training intensity dose compared to the low and moderate session intensities (Campbell et al. 2020). Only subscales of fatigue and soreness showed an adverse increase in scores from pre- to 24 h post-trial (Campbell et al. 2020). These findings support the use of various well-being subscales, with specific reference to fatigue and soreness, to assess the time course needed for sufficient post-session athlete recovery (Campbell et al. 2020).

In a study conducted by Gallo, Cormack, Gabbett and Lorenzen (2015) in professional Australian football players during the pre-competition phase, a reduction in well-being *z*-score of -1 was associated with a two to nine percent decrease in running performance (i.e. average speed and high speed running) during training sessions. In addition to these findings Malone et al. (2018) reported negative changes ranging between 3.1-4.9% in various running performance variables (total high-speed distance, high speed distance, maximal velocity, maximal velocity exposures) in trainning sessions, within a competitive season in male elite soccer players, when reported well-being experienced a a negative change in z-score of -1. However with the associated decline in running performance variables and well-being, players develop pacing strategeties to achieve similar running performance outputs during training sessions by completing higher percentages of workload at lower intensities of running (Malone et al. 2018). The authors concluded that monitoring pre-training perceived well-being may provide predictive information regarding the external workload that can be expected from individual players during a training session (Malone et al. 2018). Wellman et al. (2019) investigated the association between external workload in the form of running performance variables during pre-season training sessions that involved match play (Saturday) on next-day (Sunday) well-being in male collegiate football players as well as 48 h prior to matches (Thursday). Findings indicated significant (p<0.05) positive relationships between well-being reported on the Sunday and running performance variables (TD, low and medium intensity running distance covered, acceleration and deceleration distance at all intensities) recorded on the previous day during match play (Wellman et al. 2019). In summary, the monitoring of well-being during the pre-competition phase of training may assist sport scientists and coaches in understanding the training response, and provide guidance in adjusting the individual training load prescription toward performance in competition (Wellman et al. 2019).

In contrast to the findings emphasising the strength of relationships between training workload and well-being during periods of training (Saw et al. 2015), a study conducted by Thorpe et al. (2015) in elite male soccer players reported trivial, non-significant relationships between day-to-day well-being and training workload during a short in-season competitive phase of training that included match-play (17 days). The variability in both day-to-day well-being and running performance may have resulted from the focus of training sessions between matches shifting more towards recovery and maintenance of physical performance and away from high volume or intensity of training (Thorpe et al. 2015).

Relationships between weekly well-being profiles with, respectively, internal workload, the length of the match-match cycle, and stage of season were investigated in male professional football players during a competitive season which included both training sessions and matches (Gallo et al. 2016). Interestingly, internal workload reported post-match had negligible or unclear relationships with weekly well-being, while the length of match-match microcycle (6-day, 7-day or 8-day) had significant bearing on weekly well-being profiles (Gallo et al. 2016). Well-being scores took between four to six days to return to baseline levels, with the response being magnified during the shorter match-match microcycles (Gallo et al. 2016). Thus, it was suggested that players' perceived well-being status was largely dependent on the number of days between matches, i.e. the recovery period (Gallo et al. 2016).

Mendes et al. (2018) reported significantly higher (adverse) well-being scores during training weeks where two or more matches were played (termed congested match-play) in comparison to that of regular or preparatory weeks throughout the course of a competitive season in elite male volleyball players. It was reported that during training periods of congested match-play the worst well-being scores were evident on the day after a match, and the most favourable scores were reported on the morning prior to the match (Mendes et al. 2018). Clemente et al. (2017) observed significantly higher (adverse) responses of well-being (fatigue, soreness and stress) during congested weeks of match-play (two matches played per week) in professional soccer players. The authors attributed findings of worsened well-being during congested fixtures to increased workload, accumulated fatigue and various psychological stressors related to competition (Clemente et al. 2017).

Rabbani, Baseri, Reisi, Clemente and Kargarfard (2018) compared changes in well-being scores of male collegiate soccer players during high-workload periods of congested competition with low-workload periods of training. Moderate deteriorations in sleep quality, stress, muscle soreness, and fatigue were observed during congested match-play fixtures when compared to normal training weeks (Rabbani et al. 2018). Thus, congested match-play was associated with worse well-being, indicating increased fatigue and lower recovery (Rabbani et al 2018). The authors concluded that subjective self-reported measures of well-being were more sensitive to increases in training load than objective measures of heart rate variability (HRV), and should therefore be prioritised during congested match-play periods toward decision making for individual player recovery (Rabbani et al. 2018).

Studies by Ihsan et al. (2017) and McGuinness et al. (2018) investigating the demands of congested competition on well-being, internal workload and match running performance variables in elite male and female field hockey players will be discussed in section 2.2 of the dissertation.

Finally, the researcher agrees with Linqvist (2011) that the customisation of well-being questionnaires may pose a challenge to the standardisation of assessment tools and should be taken into consideration when interpreting findings presented in literature. Although the athletes' responses are presumed to be honest and accurate, Thornton, et al. (2016) reported that players may misrepresent responses in order to manipulate the perceptions of coaching staff. The following paragraphs will unpack the subscales of well-being measured in the current study.

Motivation can be defined as "something that gets us going, keeps us moving, and helps us get the job done" (Woodruff & Scallert, 2008: pp 35). Benefits and possible factors driving motivation for athletes participating in sport may be enjoyment, the pursuit of career goals, and/or the perceived elevation of status in society (Surujlal et al. 2013). It is suggested that even though limited research has been conducted on motivation as a component of well-being within sport, when athletes are placed in environments or situations where several stressors are experienced at once, adverse effects on motivation may result (Linqvist, 2011, Surujlal et al. 2013).

Sleep is considered essential for both mental and physical recovery, especially for athletes who participate in regular physical training (Juliff, Halson and Peiffer, 2015; Monma, Ando, Asanuma, Yoshitake, Yoshida, Miyazawa, Ebine, Takeda, Omi, Satoh, Tokuyama & Takeda, 2018; Mah, Kezirian, Marcello & Dement, 2018). In fact, sleep is suggested to be the single most effective recovery strategy for athletes (Juliff et al. 2015). Substantial research carried out on athletes' sleep suggests that inadequate quality and quantity of sleep may have adverse effects on physical and cognitive performance and elevate the risk of illness and injury (Juliff et al. 2015; Monma et al. 2018). Insufficient amounts of sleep may lead to adverse effects on metabolism, physical performance and endocrine function, and raise perceptions of exertion during exercise (Mah et al. 2018).

Disturbance in sleep may arise from a combination of factors including lifestyle habits, psychological distress, or the strains of competition or training (Monma et al. 2017). Up to 31% of top athletes may suffer from some sort of sleep disorder (Monma et al. 2018). Juliff et al. (2015) investigated the disturbance of sleep prior to competition in international and professional athletes over a period of 12 months and found that up to 64% of the athletes experienced sleep irregularities prior to a major competition. Research performed on elite athletes during periods of congested competition has shown declines in sleep quality (McGuinness et al. 2018; Mendes et al. 2018). The authors attributed the results to the off-field demands of congested competition fixtures which include the adjustment to new schedules (McGuinness et al. 2018; Mendes et al. 2018). Although little research is available on sleep quality, patterns and disturbances during competition periods, anecdotal reports suggest that athletes sleep worse during these periods (Juliff et al. 2015).

Stress, otherwise referred to as psychological stress, can be defined as "a state of mental or emotional tension resulting from adverse or demanding circumstances" (Mann, Bryant, Johnstone & Ivey, 2015:2). Various stress-injury models suggest that when athletes participate in strenuous training or competition, their personal history of stressors, traits and coping strategies will influence their individual response (Mann et al. 2015). Individuals who are unable to respond appropriately (e.g. who feel overwhelmed by the physical or mental strain) may be placed at an increased risk of injury (Mann et al. 2015). This relationship between stress and physical health is paramount in populations such as student-athletes where they experience various life stressors while participating in demanding sporting regimes (Surujlal et al. 2013; Mann et al. 2015). Gayles (2009) reported that student-athletes may complete up to 20 hours of sport engagement (practice and matches) per week during the competition season.

The training and competition demand may require them to miss lectures or neglect academic commitments, which may add to the psychological stress they experience (Gayles, 2009). Thus, stress (and other subscales of well-being) are not only influenced by workload and changes thereof, but also by independent factors such as concerns over performance, interpersonal relationships, the team environment and team culture (Clemente et al. 2020). Research on elite athletes during periods of congested competition has shown elevated stress (Mendes et al. 2018; Clemente et al. 2020). The finding was attributed to changes in schedule, disruption in sleeping patterns and increased perceived stress of performance (Mendes et al. 2018; Clemente et al. 2020).

Globally, considerable financial and human resources are put forth to develop and implement athlete monitoring systems in the hope of managing and minimising the adverse effects of fatigue on athletes (Thorpe et al. 2017). Persistent high levels of fatigue are associated with increased risk of injury and illness (Thorpe et al. 2017). Training and competition impose demands on athletes which shift the well-being status along a continuum ranging from acute fatigue to OTS in severe cases (Saw et al. 2015; Soligard et al. 2016). Progression into a state of excessive fatigue or OTS has been associated with decreases in various self-reported measures of physical and psychological well-being (Saw et al. 2015). The inability to detect such changes can result in an increased risk of illness and injury, emphasising the need for continuous assessment of well-being responses for daily fluctuations and trends (Saw et al. 2015; Soligard et al. 2016).

Fatigue can be defined as “the inability to complete a task that was once achievable within a recent time frame” (Halson, 2014:140). In an attempt to gauge fatigue in elite team sport athletes, objective measurements for recovery status have been used (Thorpe et al. 2017). The objective measures used to assess recovery status have been summarised by Thorpe et al. (2017) as tests for: physical performance (single or repeated sprints, time trials, and tests requiring maximal voluntary muscle contractions), neuromuscular function (countermovement jump and squat jump), autonomic nervous system activity (heart rate [HR] responses during rest, exercise, and/or recovery, and HRV), as well as biochemical, hormonal or immunological markers (creatine kinase, C-reactive protein and interleukin-6). A decrease in fatigue is inferred from improvements of recorded results closer towards pre-exertion levels (Thorpe et al. 2017). However, the regular application of inferred measures of fatigue are limiting due to their expense and exhaustive/invasive nature (Drew & Finch, 2016; Thorpe et al. 2017). Subjective measures in the form of ratings of fatigue through questionnaires have been found to be more practical, cost-effective and sensitive to changes in training load (Saw et al. 2015; Drew & Finch, 2016; Thorpe et al. 2017).

Cosh and Tully (2015) reported fatigue to be a key stressor for student-athletes, potentially leading to adverse effects on sports performance and decreased cognitive function during academic endeavours. A study conducted by Clemente et al. (2020) on elite professional basketball players over a competitive season reported strong positive relationships between reported fatigue and internal workload in the form of session rating of perceived exertion (sRPE).

Muscle soreness, or soreness, may be associated with athlete self-reported injury symptoms to a specific body region, in that athletes perceive their participation in physical activity being impeded by the sensation (Drew & Finch, 2016). Other sources in athlete monitoring literature have described muscle soreness as the extent of delayed onset of muscle soreness (DOMS) (Clemente et al. 2017; Mendes et al. 2018, Clemente et al. 2020). In a review of literature conducted by Drew and Finch (2016), a dose-response relationship between training load and scores of soreness has been indicated. In agreement with this, a study by Clemente et al. (2017) on male elite professional soccer players during a competitive season reported that during congested training weeks (i.e. when several matches were played), soreness (rated as the extent of DOMS) was significantly elevated in comparison to regular training weeks. Mendes et al. (2018) reported similar findings in elite male volleyball players over a competitive season, where reported soreness scores remained elevated throughout more intense or congested weeks in comparison to less intense weeks when recovery featured more prominently. Literature suggests that levels of soreness reported the day after match play may take between 48-72 hours to return to pre-exertion levels. In conclusion, monitoring soreness (whether it be defined as DOMS or general body soreness) during congested periods of competition is indicated due to the association with injury susceptibility and impeded physical exertion (Mclean, Coutts, Kelly and McGuigan, 2010; Mendes et al. 2018; Wellman et al. 2019).

The perception of “energy” or energy levels is suggested as important for evaluating overall athlete well-being (Saw et al. 2015). However, a clear definition of the term as used within athlete monitoring is still to be found. One can argue that motivation (as defined earlier in this section) may be very similar to energy levels. In agreement with Saw et al. (2015), there is a lack of literature reporting on fluctuations in perceived energy levels during training and competition.

2.1.2 External workload

Field-based team sports require to some extent the ability to sustain intermittent bouts of high-intensity as well as execute repetitive actions of change of direction in the form of acceleration and deceleration (Rampinini, Alberti, Florenza, Riggio, Sassi, Borges & Coutts, 2014). External workload, as indicated by match running performance, is commonly quantified using global positioning system (GPS) wearable technology (Aughey, 2011; Rampinini et al. 2014; Ihsan et al. 2017; Malone et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018; Wellman et al. 2019). GPS-derived metrics provide valuable information in the form of running performance variables that may elucidate the demands of training and competition (Malone et al. 2017; Whitehead, Till, Weaving & Jones, 2018). In match play, GPS-derived information assists in providing a comprehensive overall assessment of temporary/acute fatigue, match segment demands, as well as the fluctuation in match demands (Whitehead et al. 2018). GPS technology is further used to profile match and position-specific demands, and provide a means of assessing adaptive responses to training programmes (Drew & Finch, 2016; Malone et al. 2017; McGuinness et al. 2017; McLaren et al. 2017; McGuinness et al. 2018).

It is important to note that the interpretation of GPS results should be done knowing the data capturing validity and reliability of the device (Rampinini et al. 2014; Whitehead et al. 2018). The ability to make sound comparisons between GPS devices is complicated as a result of the numerous brands and manufacturers, and several different methods used to assess the validity and reliability of these devices (Aughey, 2011; Rampinini et al. 2014). Research suggests that factors influencing the accuracy and reliability of a GPS device is the sampling rate of the device itself, as well as the speed and duration of the exercise task at hand (Aughey, 2011; Rampinini et al. 2014). The use of GPS devices with higher sampling rates of up to 10 Hz compared to those of lower sampling rates (1 Hz and 5 Hz), have reported higher levels of accuracy (between 30-50%) with regards to total distance (TD) and high-intensity running distance (Rampinini et al. 2014). Furthermore, research has also reported that levels of validity and reliability decrease when the velocity of the movement increases, such as during task involving a rapid change of direction, or acceleration and deceleration (Aughey, 2011).

In female field-based team sports such as soccer, field hockey and rugby, the use of GPS technology to assess match running performance, fatigue related variables and training intensity is common practice (Hodun, Clarke, De Ste Croix & Hughes, 2016). Common GPS-derived measurements used by practitioners to quantify external workload are TD covered, distance covered in predetermined running speed zones, distance covered above and below a predetermined running speed threshold classified as either high or low intensity running, and distance covered per minute of play representative of the individual's work rate (Hodun et al. 2016; Ihsan et al. 2017; Malone et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018; Wellman et al. 2019). The implementation of GPS technology in field-based team sports is utilised in profiling match and position-specific demands, as well as providing a means of assessing adaptive responses to training programmes (Drew & Finch, 2016; Malone et al. 2017; McGuinness et al. 2017; McLaren et al. 2017; McGuinness et al. 2018).

In a review of female field-based team sports and the use of GPS technology in competitive match play, it was reported that elite female soccer players completed distances of up to 9997 ± 928 m with average work rate scores of 111 $m\cdot min^{-1}$ (Vescovi, 2012). A study carried out on elite female soccer players by Hewitt, Norton and Lyons (2014) reported similar results in scores of TD (9631 ± 175 m) and average work rate (107 $m\cdot min^{-1}$). It should be noted that there are several other variables assessed such as the distance covered in specific speed zones or above speed thresholds which may be valuable to practitioners. However, the comparison between sports or even within sports lacks standardisation and is difficult as they are highly specific to the sport as well as the practitioner involved (Hodun et al. 2016). Furthermore, the use of GPS technology and the data/information it provides practitioners and coaches with, play a significant role in improving gender-specific training and the effectiveness of athlete monitoring relating to potential risk of running-based injury (Hodun et al. 2016).

2.1.3 Internal workload

In field-based team sports, internal workload is commonly quantified by assessing athlete physiological and/or psychological responses (Drew & Finch, 2016; McLaren et al. 2017). Daily measurements for internal workload may include sRPE, the calculation of internal workload using the product of sRPE and session duration (i.e. the sRPE-method), and the HR response to an external workload (Drew & Finch, 2016; Haddad et al. 2017; McLaren et al. 2017). The sRPE and the sRPE-method are regularly incorporated in athlete monitoring approaches as they are non-invasive and require minimal financial cost (Haddad et al. 2017).

The use of sRPE as a tool to quantify internal workload is supported by substantial research in the field of sport science (Drew & Finch, 2016; Haddad et al. 2017; McLaren et al. 2017). The sRPE is indicated by recording the athlete's rating of perceived exertion (RPE) for the session or match on a modified Borg category ratio 10 (CR-10) scale (Forster et al. 2001; Haddad et al. 2017). Factors – other than physical exertion - that may influence sRPE rating by athletes are gender, age, level of experience and perceived physical performance (Haddad et al. 2017). The reporting of sRPE requires very simplistic instruction and is a valid and reliable tool to quantify internal workload in a variety of exercise modalities (Foster et al. 2001).

Foster (2001) developed and validated the sRPE-method to quantify training load indicative of the athlete's perceived intensity or hardness of the session or match (Foster et al. 2001; Haddad et al. 2017; McLaren et al. 2017). A score for internal workload is calculated by multiplying sRPE by the session duration in minutes to represent overall session "hardness" in Arbitrary Units (AU) (Foster et al. 2001; Haddad et al. 2017; McLaren et al. 2017). The sRPE-method was developed to eliminate the need to utilise HR monitors or other methods of assessing exercise intensity (Halson, 2014). Literature supports the use of the sRPE-method for quantifying internal workload in periods of both training and competition (Haddad et al. 2017). However, it should be noted that the use of the sRPE-method during competition poses practical challenges as, in contrast to training where the session duration is most likely pre-determined, player session duration (match time) in field-based team sports is dynamic in nature and difficult to control (Haddad et al. 2017).

In a recent meta-analysis on the relationships between internal and external measures of training load in team sports, sRPE and internal workload consistently demonstrated strong positive relationships with external workload variables. This was especially true for total running distance covered in both matches and training (McLaren et al. 2017). Strong associations between increased risk of injury and sRPE have been demonstrated in periods of rapid changes of acute training workload (Hulin et al. 2015; Drew & Finch, 2016; McGuinness et al. 2018). In contrast to the extent of literature available on the relationships between internal and external workload variables, there exists a dearth in literature on the nature and strength of relationships between well-being responses and internal workload (Clemente et al. 2020).

2.1.4 Quantification of total workload

Workload is assessed either in absolute terms as the sum of a series of training and/or competition workloads, or in relative terms by expressing the change in workload in specific time periods (Drew & Finch, 2016). Within relative workloads, concepts such as training stress balance (TSB), or otherwise known as the acute:chronic workload ratio (ACWR), can be used to compare the average acute workloads over different time periods. In this regard, the average incurred workload during a seven-day period can be compared to that of a previous 28-day period of training (Drew & Finch, 2016). The ACWR in recent literature has been reported to be a valuable tool in injury risk assessment and monitoring in athletes (Bourdon et al. 2017).

Current literature supports the notion that high levels of both absolute and relative chronic training workloads are effective in eliciting adaptation, thereby promoting protective effects in athletes (Soligard et al. 2016; Bourdon et al. 2017). However, in periods of rapid and sporadic increases in acute workload, athletes are placed at a higher risk of injury and Illness (Soligard et al. 2016). Thus, the rapid increase in acute workload along with less recovery between matches, as is evident during a congested competition schedule, may place athletes at risk for progressing into fatigue, illness, injury or OTS. Current research suggests subjective self-reported measures to be superior in validity for measuring the response to internal workload changes in comparison to objective measures (Saw et al. 2015; Wellman et al. 2019). Such changes may be in either acute or chronic workload, and during training or competition (Saw et al. 2015; Wellman et al. 2019). In conclusion, the integration of well-being, internal and external workload monitoring is needed for practitioners to gain an insight into the total workload placed on athletes (Saw et al. 2015, Soligard et al. 2016).

2.2 Field hockey

2.2.1 The sport of field hockey

Field hockey is a popular field-based team sport with origins dating back to as early as 1000 BC (FIH, 2019). Notable landmarks achieved in the sport was its Olympic debut in London in 1908, and the establishment of the International Hockey Federation (FIH) in 1924 (FIH, 2019). A recent growth in research within field hockey investigating external workload, internal workload and well-being (Ihsan et al. 2017; McGuinness et al. 2018) is noticeable, however a dearth in research exists with regards research of this nature in congested periods of competition and in female subjects (McGuinness et al. 2018).

Field hockey is a team-based, stick-and-ball sport which involves various locomotive actions of high-speed running, accelerations, decelerations and those that require a quick change of direction (McGuinness et al. 2017). While the sport is intermittent in nature, the majority energy system contribution is aerobic (McGuinness et al. 2017). Players are required to perform a considerable number of low-speed running bouts interspersed with short periods of high-speed running in response to the dynamic tactical demands of the sport (McGuinness et al. 2017). The current match format comprises four quarters of 15 min each, with two min separating quarters 1 and 2, and quarters 3 and 4, and seven min separating quarters 2 and 3 (McGuinness et al. 2018). Recent rule changes have assisted in promoting fluidity of the game, encouraging a higher intensity of play. The most notable rule changes contributing to adjusted physical, tactical and technical demands are the substitution rule change, which allows for an unlimited amount of substitutions (rolling substitutions) to be made (Lidor & Ziv, 2015). In addition to this, the game format changed from halves to quarters, and on-field rule changes reduced stoppage times during the game (Ihsan et al. 2017; FIH, 2019).

2.2.2 Athlete monitoring in field hockey competition periods

Well-being monitoring and assessment in field hockey during congested periods of competition has been carried out using customised questionnaires (Ihsan et al. 2017; McGuinness et al. 2018). Similar to the design and requirements of the current study, in studies by McGuinness et al. (2018) and Ihsan et al. (2017) participants were required to submit daily customised well-being questionnaires at a predetermined time every morning, prior to any form of exercise or matches. To the author’s knowledge, those are the only two studies to date that have investigated athlete well-being in conjunction with other forms of workload during periods of congested competition in field hockey players (Ihsan et al. 2017; McGuinness et al. 2018).

In a study conducted by McGuinness et al. (2018) on elite female field hockey players over a congested competition period requiring players to complete seven matches in 16 days, notable deteriorations in sleep quality, mood and muscle soreness were observed. In addition, substantial drops in match running performance were observed on match days where significant adverse changes in subscales of muscle soreness and sleep quality were recorded (McGuinness et al. 2018). Similar findings were observed by Ihsan et al. (2017) in elite male field hockey players over a congested period of competition as total well-being (calculated as the summation of fatigue, muscle soreness, mood state, and sleep quality subscale scores) deteriorated throughout the competition. Both studies suggest a significant factor contributing to these results is the accumulation of fatigue, as well as various psychological factors associated with progress in the competition (Ihsan et al. 2017; McGuinness et al. 2018). As reported before, in team sports during both training and competition periods, strong relationships have been demonstrated between high-intensity running workloads and well-being subscales of fatigue and muscle soreness (Gallo et al. 2016; Ihsan et al. 2017; Malone et al. 2018; Wellman et al. 2019).

In contrast to the limited body of research on field hockey player responses in well-being to congested competition fixtures, external workload in the form of match running performance via GPS measurement has received more attention (Lythe & Kilding, 2011; Jennings et al. 2012; Ihsan et al. 2017; McGuinness et al. 2017; McMahon & Kennedy, 2017; McGuinness et al. 2018; McGuinness, Malone, Petrakos, & Collins, 2019). Research on female international-level field hockey players engaged in competitive match play recorded total running distance covered (TD) to be 5147 ± 628 m, at an average work rate of 113.0 ± 8.9 m·min^{-1}, and high-intensity (>16 km.h^{-1}) running distance covered to be 753.0 ± 33 m, at an average high-intensity work rate (m·min^{-1} run at >16 km.h^{-1}) of 16.4 ± 5.3 m·min^{-1} during matches (McGuinness et al. 2018). Similar findings were reported by McMahon and Kennedy (2017) in female international field hockey players during international matches completed throughout an annual season, with average TD and average work rate recorded as 5167 ± 1030 m and 113.30 ± 13.51 m·min^{-1} respectively. In contrast to these results Jennings et al. (2012) reported higher scores of TD in female international field hockey players during a congested competition; however this study was carried out prior to player substitution rule changes which is suggested to have had an influence on scores in comparison to current literature. Furthermore, White and MacFarlane (2015) reported that there are inconsistencies in reporting TD covered during competitive match-play due to differences in GPS data analysis procedures. The recorded TD scores by Jennings et al. (2012) for female strikers, midfielders and defenders were 9819 ± 720 m, 10,160 ± 215 m and 9453 ± 579 m respectively. These values are considerably higher than reported in a review of studies on female field hockey players where the mean distance covered during a match ranged between 5.5 - 6.6 km (Lidor & Ziv, 2015). It is suggested that possible reasons such signifcantly higher scores of TD reported by Jennings et al. (2012) could be different methods of GPS analysis (Aughey, 2011; Rampinini et al. 2014; White & MacFarlane, 2015), and the sampling rate of the GPS device (Aughey, 2011; Rampinini et al. 2014).

In comparison, match running performance measured during matches in international-level male field hockey players revealed TD covered to be 6798 ± 2009 m and high-intensity distance (>19 km.h^{-1}) covered to be 479 ± 108 m (Lythe & Kilding, 2011). Furthermore, field hockey is unique in terms of its demand placed on athletes as a result of the dynamic nature of the game, as well as the scheduling of competitive tournaments (McGuinness et al. 2018). Competitive periods in field hockey are commonly congested in nature (Ihsan et al. 2017, McGuinness et al. 2017, McGuinness et al. 2018) placing high levels of acute workload on athletes, thereby increasing the risk of injury and illness (Hulin et al. 2015, Drew & Finch, 2016, Soligard et al. 2016, Bourdon et al. 2017).

2.3 Purpose of the study

To date, findings are ambiguous regarding the strength of relationships of measures of internal workload and responses to workload (e.g. sRPE and well-being) with external workload (e.g. running performance) in team-sport athletes (Lockie et al. 2016, Malone et al. 2017, Wellman et al. 2019). In addition, student-athletes in field hockey are exposed to intense, congested competition schedules (Ihsan et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018), and the unique demands of university-level athletes (Surujlal et al. 2013; Huml et al. 2017). The dearth of research on female field hockey players during congested competition periods means that a need exists to quantify running performance demands, and investigate the associations between subjective and objective measures of internal and external workload (Ihsan et al. 2017; McGuinness et al. 2017; McGuinness et al; 2018). Therefore, the current study investigated both the day-to-day and cumulative effects of a congested competition period on female field hockey players. It is envisioned that the study will add to the existing body of knowledge on the subjective and objective demands of congested competition in student-athletes participating in team sport in general, and field hockey in particular. Quantifying these demands and exploring relationships among both the subjective and objective variables, and predictive and outcome variables, may provide insight into future athlete monitoring practices and interventions toward optimal performance, recovery and injury risk reduction.

Chapter 3

Methodology

3.1 Introduction

Athlete monitoring of workload and well-being is increasing in popularity and utilisation over a variety of team sports. Recently, several studies (Ihsan et al. 2017; McGuinness et al. 2018) have quantified various workload and/or well-being indices in field hockey players during training and match play. However, a limited number of studies have quantified these demands in female field hockey players during periods of congested competition, (i.e. a tournament). To tackle the current research problem, three main categories of variables were collected (Table 3.1): well-being, internal workload and external workload. Included below are all the methods and tools used to both collect and analyse the data. The research design, population and sampling, measurement instruments, ethical considerations, data collection and statistical analysis are described.

3.2 Research design

A descriptive, cross-sectional (observational) cohort study design was implemented. Measures of athlete well-being, internal workload and external workload were quantified, with associations between variables and changes over time explored, without manipulating any independent variables. A prospective component was present, since research was conducted in chronological order and on the same student-athletes over five consecutive days of an inter-university-level field hockey tournament (Mann, 2003). Furthermore, the study was non-experimental in design - events were analysed to explore relationships between predictor variables (e.g. well-being) and outcome variables (e.g. match running performance) in the cohort under investigation (Mann, 2003).

3.3 Population and sampling

A convenience sampling technique was utilised, as it was the only option available at the time to investigate the specific research questions posed. The student-athlete and researcher environments created by the structures and measurement systems available under the Sport, Exercise Medicine & Lifestyle Institute (SEMLI) at UP, provided opportunity for targeted research into the performance demands of inter-university level congested competition in a variety of team sports, including field hockey. Participants comprised female first-team hockey players who formed part of the TuksSport system at the University of Pretoria (UP) and were selected into that team by the coach to represent the institution at a university-level tournament. Please refer to the permission letter from TuksSport to recruit student hockey players as participants (Appendix B). The sample size was 16 participants, as regulated by University Sport South Africa (USSA). All participants were 18 years of age or older at the time of the study.

3.3.1 Inclusion criteria

- Selection into the women's field hockey team to represent UP at the USSA inter-university field hockey tournament.
- Participants had to be in good health, as determined by their inclusion in the team for competing in a tournament.

3.3.2 Exclusion criteria

- If a selected athlete was injured or fell ill, and/or could not play matches during the tournament, or withdrew from the study, they were excluded from the study.
- In line with previous research by Ihsan et al. (2017), McGuinness et al. (2017), McGuinness et al. (2018) and McGuinness et al. (2019), all data from goalkeepers (n = 2) during this study was excluded.

3.4 Measurement instruments

The Smartabase (Fusion Sport, Brisbane, Australia) athlete monitoring system is utilised as a primary tool for athlete monitoring practices within SEMLI and the TuksSport clubs, including TuksHockey. In conjunction with the implementation of this athlete monitoring system, the use of GPS wearable technology to assess external workload has also been incorporated within some of these clubs. Information sessions and trial periods are put in place at the beginning of each year, specifically pertaining

Table 3.1. Variables recorded on each of the five consecutive days of the congested field hockey tournament

Category of measurement	When recorded	How recorded	Variables measured	Unit of measurement
Perceived well-being (Subjective)	08:00-09:00 AM daily	Online questionnaire *via* Smartabase software	Well-being score (sum of scores)	Arbitrary units (AU) (/30)
			Fatigue score	AU (/5)
			Soreness score	AU (/5)
			Stress score	AU (/5)
			Motivation score	AU (/5)
			Sleep quality score	AU (/5)
			Energy score	AU (/5)
External match workload (Objective)	During match-play	Global positioning system (GPS)	Total running distance	m
			Average work rate (average running speed)	$m \cdot min^{-1}$
			High-intensity (>16 $km \cdot h^{-1}$) running distance	m
			Average high-intensity (>16 $km \cdot h^{-1}$) work rate	$m \cdot min^{-1}$
Internal match workload (Subjective)	After the match	Online calculation *via* Smartabase software	Internal workload; sRPE reported score multiplied by player match time.	AU
			sRPE reported using the Borg CR-10 scale (1-10)	AU
		SubTime online application	Player match time	min

to the athlete monitoring system, prior to the commencement of the official sport season for student-athlete participation.

3.4.1 Well-being

During the study period participants were required to complete a self-reported well-being questionnaire (Appendix A), based on research carried out by Grove et al. (2014) and Main and Grove (2009), during the hours between 08:00 and 09:00 on each day for the duration of the tournament (McGuinness et al. 2018). Athletes were asked to rate the extent of their energy levels by answering the question “are you feeling energetic, active, alert?” as stated by Main and Grove (2009) thereby clarifying the meaning of the concept “energy level”. Due to the fixture scheduling, this time of day represented approximately 2 to 8 hours prior to the match scheduled for the day.

Scores pertaining to each well-being subscale (stress, fatigue, energy levels, motivation, soreness, and sleep quality) and total well-being were inputted electronically using the Smartabase smartphone application (Malone et al. 2018; Wellman et al. 2019). The completion time of the questionnaire was approximately two to five min. Participants were requested to complete the questionnaire prior to engaging in any physical activity, and not to communicate relative data to other participants or staff to avoid any external influences. Each variable was rated on a five-point Likert scale. The scale responses ranged from “Very Low” to “Very High”. For the following subscales, a higher rating (Very High) is deemed as favourable: energy levels, motivation and sleep quality. In contrast, a lower rating (Very Low) for the following subscales is deemed favourable: fatigue, stress, and soreness. Please refer to Table 3.2 for an explanation of the scores for each subscale of well-being. To maximize compliance the researcher assessed the questionnaire completion status of all participants during the allotted time period. Participant responses were immediately stored on the Smartabase online cloud platform.

3.4.2 Internal workload

The collection of internal workload data also took place using the Smartabase athlete management system smartphone application. This was completed at a standardised time period of within 30 min post-match (Gallo et al. 2016; Ihsan et al. 2017; Malone et al. 2018). Participants were required to rate their perceptual exertion or the 'hardness' of the match using the modified Borg CR-10 rating of sRPE scale (Table 3.3) (Gallo et al. 2016; Ihsan et al. 2017; Malone et al. 2018; McGuinness et al. 2019). The internal workload of each match was determined in arbitrary units (AU) by multiplying the recorded sRPE score ranging from "1. Very, very easy" to "10. Maximal", with the total accumulated duration of match time during the match for each participant (Forster et al. 2001; Haddad et al. 2017; Ihsan et al. 2017; McGuinness et al. 2018). Please refer to Appendix C for a copy of the internal workload questionnaire used by participants to quantify sRPE and internal match workload using an application on their smartphones within thirty minutes after every training session or match. In this questionnaire, athletes recorded the session duration in minutes and the sRPE on the CR-10 scale. To ensure accuracy of match playing duration, recorded match video footage was used. Match playing duration was calculated by using a smartphone application "SubTime" (OTDSoft Incorporated): total match duration subtracted by time spent off-field or on the bench. Data was extracted to a Microsoft (MS) Excel spreadsheet (Microsoft Corp. Redmond, USA) for further analysis.

Table 3.2. Scoring of the well-being questionnaire responses (Grove et al. 2014; Malone et al. 2018; Main & Grove, 2009; McGuinness et al. 2018; Wellman et al. 2019)

Variable	Rating				
	Very low	**Low**	**Average**	**High**	**Very High**
Fatigue	1	2	3	4	5
Soreness	1	2	3	4	5
Stress	1	2	3	4	5
Motivation	5	4	3	2	1
Sleep Quality	5	4	3	2	1
Energy Levels	5	4	3	2	1

Total well-being score /30

Table 3.3. Modified Borg CR-10 scale modified by Foster et al. (2001) to assess sRPE

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

3.4.3 External workload

External workload, as indicated by match running performance metrics measured during hockey matches, was quantified using the Polar Team Pro system (Polar Electro Oy, Kempele City, Finland) (Figure 3.1). The manufacturer specifications of the Polar Team Pro system are stated as follows: Polar Team Pro Sensor (integrated GPS,10Hz, MEMS Motion sensor, 200Hz, weight: 39 g, dimensions 36 mm x 68 mm x 13 mm), and Polar Team Pro soft HR strap (weight: 30 grams). Match running performance variables were classified and quantified according to current literature on international female field hockey players (McGuinness et al. 2017; McGuinness et al. 2018). The four external workload variables obtained from the measurement of match running performance, and used for statistical analysis, were total distance (TD) covered (m), average work rate ($m{\cdot}min^{-1}$) as TD covered per minute of actual match time, high-intensity (>16 $km.h^{-1}$) running distance (m), and average high-intensity (>16 km.h^{-1}) work rate (m·min^{-1}) as total high-intensity distance covered per minute of actual match time (McGuinness et al. 2017; McGuinness et al. 2018).

Figure 3.1: Polar Team Pro, strap and belt

Each participant was assigned a GPS sensor and HR strap for the duration of the study. Data recording commenced 30 min prior to the start of each match and was terminated at the conclusion of each match. Data was recorded live via the Polar Team Pro system application. The calibration and satellite signal alignment of equipment took place during the 30-min warm-up period (Wellman et al. 2019). Heart rate straps were placed around the participants' chests, slightly inferior to the line of the sternum, with the HR sensor located anteriorly. The GPS sensors were then attached to the HR straps, which initiated the data recording process. At the conclusion of each match, participants were instructed to remove and hand in all equipment to the researcher. All GPS sensors were attached and synchronized with the base station and uploaded to the Polar Team Pro web service platform. Relative time points of the match, including quarter end and start times, were tagged for data analysis. Data cleaning was conducted using recorded tagged time points. Match running performance variables were then exported from the Polar Team Pro web service platform into a Microsoft (MS) Excel spreadsheet (Microsoft Corp. Redmond, USA) for further statistical analysis.

3.5 Data analysis

An independent statistician from the Internal Statistical Consultation Services at UP assisted with the statistical analysis. Variables in each category were described, and the relationships between variables determined. Please refer to Appendix D containing the letter confirming support for the proposed analysis. Transfer and interpretation of data analysis and results were conducted by the researcher with the guidance of a University of Pretoria-based statistician.

Descriptive statistics, expressed as mean, standard deviation (SD) and range, were calculated for all outcome variables for each day, and for the tournament overall. Normality of data distribution was checked using the Shapiro-Wilk Test. For all null hypothesis tests, statistical significance was considered as $p < 0.05$. Depending on the outcome of the normality test, parametric (Pearson correlation coefficient) or non-parametric (Spearman rank order correlation coefficient) bivariate correlation analysis was conducted to determine the direction (positive or negative), strength and significance of the relationships between: (a) athlete well-being scores and external workload scores, (b) athlete well-being scores and internal workload scores, and (c) external workload scores and internal workload scores. The correlation coefficient was accompanied by a 95% confidence interval (CI) which provides the range of plausible values of the coefficient in the population under investigation (Schober, Boer & Schwarte, 2018). The conventional approach toward interpreting the strength of the correlation coefficient was followed when the range of the 95% confidence interval is narrow (Table 3.4).

Within-group analyses on each outcome variable was conducted using one-way repeated measures analysis of variance (ANOVA) (parametric analysis) or the Friedman Test (non-parametric analysis) to determine whether significant changes existed over the time course of the tournament. Where significant changes were detected, pairwise comparison tests (parametric analysis) or Wilcoxon signed rank tests (non-parametric analysis) was performed to determine the two time periods between which the statistically significant changes occurred. Furthermore, if statistically significant changes were noted over two time periods, the magnitude of the difference was calculated as Cohen's *d* to indicate the effect size (Sullivan & Feinn, 2012). The magnitude of the difference was described according to the following thresholds: 0–0.1 is trivial, 0.2–0.4 is small, 0.5–0.7 is moderate, 0.8–1.2 is large, 1.3 or greater is very large (Sullivan & Feinn, 2012). Lastly, in order to derive the best combination of variables which explained relationships between scores, multiple linear regression models were applied where: (a) the daily external workload scores were the dependent variables, and the seven well-being scores (i.e. total well-being score and the six well-being subscale scores) were the independent variables; and (b) the seven well-being scores of each day (Day 2 to Day 5) were the dependent variables and the external workload scores of the preceding day were the independent variables.

Table 3.4. Conventional approach to interpreting the correlation coefficient

Absolute magnitude of observed correlation coefficient	**Interpretation**
0.00-0.10	Negligible correlation
0.10-0.39	Weak correlation
0.40-0.69	Moderate correlation
0.70-0.89	Strong correlation
0.90-1.00	Very strong correlation

3.6 Ethical considerations

The current study formed part of a broader umbrella study with the title “Student-athlete health, well-being and sports performance: A prospective study of 5 years”, which received approval from the Research Ethics Committee of the Faculty of Health Sciences (reference number 83/2016). Informed consent and permission to use of the data that was collected and obtained electronically from all participants at the beginning of the year when they joined as (or continued being) members of the TuksSport Hockey Club as per the approved umbrella project protocol. Please see Appendix E for a copy of the informed consent form. The informed consent forms were studied online by all participants as part of an extensive information contact session hosted by the researcher and head administrator of the Smartabase athlete monitoring system of SEMLI at the TuksHockey Clubhouse, Hillcrest Campus, UP, on 30th January 2019. Therefore, athletes were fully informed about the purpose of the study, the testing to be undertaken, the possible risks relating to the study, and their right to withdraw from the study at any stage without reason or prejudice by reading the relevant document online (Appendix E) and through personal interaction. At the information session, athletes could electronically nominate aspects of the study that they did, or did not, wish to participate in. Furthermore, the participants had the opportunity to ask questions, which were answered fully, before voluntary electronic informed consent was obtained.

The research study was carried out in accordance with the Declaration of Helsinki regarding research involving human participants. The anonymity of all participants was upheld throughout the duration of the study and was maintained post completion of the study. Beyond normal and expected exposure to the demands and risks of competition, at no time were the participants placed at an increased risk of harm, undue fatigue, or compromised performance during the competition period. Both the participants and researcher, due to their daily involvement with the sport, were aware of the inherent risk of participation in field hockey.

A second information session prior to the commencement of the study was scheduled to ensure participants were familiar with the procedures, expectations, risks, and benefits of participating in the research study. Participants were also informed that, should they wish to get feedback regarding individual data given and collected during the research period, they may do so by contacting the researcher directly after the conclusion of the study period. During the research period, the researcher ensured that if the need arose to provide additional information to participants during the research period, such feedback was standardised to prevent undue influence on further responses.

The handling of all equipment and data during the research study was confined to the researcher, in order to protect the participants and maintain standardisation of procedures. This included organisation of raw data into MS Excel (Microsoft Corp. Redmond, USA) spreadsheets. All permission letters from the governing institution for approaching the participants (TuksSport), and from SEMLI for use of measurement tools, equipment, and data can be found in appendices to this dissertation. Please see Appendix B for a copy of the permission letter for UP student-athlete recruitment, and Appendix F for a copy of the permission letter from SEMLI for the use of measurement tools, equipment and data. This study received approval from the Research Ethics Committee of the Faculty of Health Sciences, UP, approval number: 452/2019 (Appendix G).

Chapter 4

Results

4.1 Introduction

This section reports the results of the descriptive and inferential analyses conducted on data collected over six consecutive days of a competitive tournament in female student field hockey players. Matches were played on Day 1-5, with group-stage or placement games from Day 1-3, and the semi-final and final of the competition on Day 4 and 5 respectively. This was the competition path for the team of participants under investigation. In the following sections, for each variable assessed, the daily score represents the mean or median of the group of participants, while each overall score represents the mean or median score over all days of the tournament for the group.

4.2 Descriptive results

Variables reported in this section are summarised under the major categories of participant characteristics, external workload, internal workload, and athlete well-being, and are presented in Tables 4.1-4.4. Results are arranged by day (match) and as the tournament average.

Table 4.1. Physical and hockey playing characteristics of participants (n = 16)

Physical characteristics	
Age (y)	20 ± 2
Stature (cm)	163 ± 6
Mass (kg)	63 ± 9
Playing age	
Hockey playing age since start of provincial representation (y)	3 ± 2
Hockey playing age since start of national representation (y)	1 ± 2
Hockey playing age since start of high school (y)	7 ± 2

All data are presented as mean ± SD. Hockey playing age refers to the number of years players participated at a specific level.

4.2.1 Participant characteristics

Table 4.1 displays demographic, physical and sport participation characteristics of the female student-athlete participants (n = 16) in this study. Mean ± standard deviation (SD) age was 20 ± 2 y, with hockey playing age at provincial and national level being 3 ± 2 (range: 0 - 7) y and 1 ± 2 (range: 0-4) y, respectively. In relation to this, the average playing age since high school was 7 ± 2 (range: 6 - 11) y. The group therefore represented experience field hockey players. All participants were outfield players (i.e. no goalkeepers were included in this study) and represented the following positions: defenders (n = 6), midfielders (n = 4), forwards (n = 6).

4.2.2 Well-being

Higher scores (arbitrary units, AU) for all well-being subscales (score range: 1 to 5) and total well-being (score range: 5 to 30) represent a worse state of well-being whereas lower scores represent a better state on each variable (see Chapter 3). Since the majority of well-being variables were not normally distributed, scores were reported as median (interquartile range, IQR). Median total well-being score over all days sampled was 15.0 (13.0 - 18.0) AU (Table 4.2). Daily total well-being scores on

Table 4.2. Well-being profiles of university female hockey players (n=16) during a congested hockey competition period

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	**Overall**
Total well-being (AU)	12.5 (11.8 - 14.0)	13.5 (12.8 - 17.25)	14.0 (12.8 - 16.5)	15.0 (12.0 - 16.3)	15.0 (13.0 - 8.0)	19.5 (17.0 - 20.3)	15.0 (13.0 - 18.0)
Fatigue (AU)	2.0 (1.8 - 3.0)	2.0 (2.0 - 3.0)	2.0 (2.0 - 3.0)	2.5 (2.0 - 3.0)	3.0 (2.8 - 3.0)	4.0 (3.0 - 4.3)	3.0 (2.0 - 3.0)
Energy levels (AU)	2.0 (2.0 - 3.0)	3.0 (2.0 - 3.0)	3.0 (2.0 - 3.0)	3.0 (2.0 - 3.0)	2.0 (2.0 - 3.0)	4.0 (3.0 - 4.0)	3.0 (2.0 - 3.0)
Stress (AU)	2.0 (2.0 - 3.0)	2.0 (2.0 - 3.0)	3.0 (2.0 - 3.0)	3.0 (2.0 - 3.3)	3.5 (3.0 - 4.0)	2.0 (1.0, 2.0)	3.0 (2.0 - 3.0)
Motivation (AU)	2.0 (1.0 - 2.0)	2.0 (2.0 - 2.3)	2.0 (2.0 - 2.3)	2.0 (1.0 - 2.0)	2.0 (1.0 - 2.0)	3.0 (2.0 - 4.0)	2.0 (2.0 - 3.0)
Sleep quality (AU)	2.0 (2.0 - 2.0)	2.5 (2.0 - 3.0)	2.0 (2.0 - 3.0)	2.5 (2.0 - 3.0)	2.0 (1.0 - 3.0)	3.5 (3.0 - 4.0)	2.0 (2.0 - 3.0)
Soreness (AU)	2.0 (1.0 - 2.3)	2.5 (2.0 - 3.0)	2.5 (2.0 - 3.0)	3.0 (2.0 - 3.0)	3.0 (2.8 - 3.0)	3.0 (2.8 - 4.0)	3.0 (2.0 - 3.0)

All data is presented as median (IQR). AU = arbitrary unit match days ranged from 12.5 (11.8 - 14.0) AU on Day 1 to 15.0 (13.0 - 18.0) AU on Day 5 and was markedly higher on Day 6 (19.5; 17.0–20.0 AU), the day after the tournament was completed.

4.2.3 External workload

External competition workload variables recorded during match play are presented in Table 4.3. Over the five competition days median (IQR) total distance (TD) was 4,545 (3,834 - 5,305) m, average work rate was 116.8 (104.0 - 123.1) m·min^{-1}, high-intensity distance (HID) (i.e. distance run >16 km·h^{-1}) was 383 (257 - 538) m, and average high-intensity work rate was 11.1 (5.8 - 14.9) m·min^{-1}. Scores [median (IQR)] of HID were highest for the match on Day 2 [435 (290 – 517) m] and lowest on Day 1 [312 (198 – 421) m]. Scores [median (IQR)] of average work rate were highest for the match on Day 2 [122.6 (109.9 - 122.9) m·min^{-1}], and lowest on Day 3 [113.4, (104.8 - 124.2) m·min^{-1}]. Average high-intensity work rate was lowest on Day 1 [9.3 (5.0 - 11.2) m·min^{-1}] and highest on Day 4 [13.4 (5.5 - 16.4) m·min^{-1}].

Table 4.3. External workload profiles of university female hockey players (n=16) during a congested competition period

	Day 1	Day 2	Day 3	Day 4	Day 5	**Overall**
TD (m)	4,460 (3,924 - 5,048)	4,773 (4,048 - 5,341)	4,308 (3,824 - 4,890)	4,350 (3,632 - 5,233)	4,623 (3,647 - 5,497)	4,545 (3,834 - 5,305)
HID (m)	312 (198 - 421)	435 (290 - 517)	359 (242 - 507)	430 (300 - 556)	357 (281 - 684)	383 (257 - 538)
Average work rate (m·min^{-1})	113.6 (102.5 - 118.6)	120.5 (109.9 - 122.9)	113.4 (104.8 - 124.2)	122.6 (102.8 - 125.7)	115.2 (104.5 - 120.9)	116.8 (104.0 - 123.1)
Average high-intensity work rate (m.min^{-1})	9.3 (5.0 - 11.2)	11.7 (7.2 - 13.3)	10.0 (6.1 - 14.4)	13.4 (5.5 - 16.4)	11.9 (6.0 - 15.4)	11.1 (5.8 - 14.9)

All data is presented as median (IQR). TD = Total distance. HID = High Intensity Distance. Average work rate (m.min^{-1}) refers to total distance covered relative to player match time. Average high-intensity work rate (m.min^{-1}) refers to high intensity-running distance >16 km.h^{-1} relative to player match time.

4.2.4 Internal workload

The internal workload of players is presented in Table 4.4. Over the course of the tournament, median (IQR) player match time and workload were 39.1 (32.9 - 47.6) min and 287 (214 – 355) AU, respectively. The lowest internal workload scores were reported on Day 1 [264 (208 – 325) AU] and the highest on Day 5 [355 (192 – 546) AU]. The overall sRPE score for the competition period was recorded as 7 (6.0 – 8.0) AU, with the lowest and highest reported sRPE scores reported on Day 2 [6.5 (5.8 – 7.0) AU] and Day 5 [9.0 (7.8 – 9.3) AU] respectively.

Table 4.4. Internal workload of university female hockey players (n=16) during a congested competition period

	Day 1	Day 2	Day 3	Day 4	Day 5	**Overall**
Player match time (min)	40.3 (35.8 - 46.3)	39.1 (34.4 - 47.0)	34.8 (32.5 - 47.3)	37.1 (31.9 - 46.0)	43.0 (29.9 - 55.7)	39.1 (32.9 - 47.6)
Internal workload (AU)	264 (208- 325)	258 (222- 315)	279 (213- 408)	300 (260- 364)	355 (192- 546)	287 (214- 355)
sRPE	7.0 (6.0 - 7.0)	6.5 (5.8 - 7.0)	7.5 (6.8 - 8.0)	8.0 (7.8 - 8.3)	9.0 (7.8 - 9.3)	7.0 (6.0 - 8.0)

All data is presented as median (IQR). AU = Arbitrary unit. sRPE = session rating of perceived exertion. Internal workload is derived from session rating of perceived exertion (sRPE) score multiplied by player match time.

4.3. Correlation analysis

Two main subsections are provided here: the first section (4.3.1) reports on the relationships between variables on the same day of the tournament, whereas the second section (4.3.2) reports the relationship of external and internal competition workload variables for each day with well-being scores obtained on the morning of the following day.

4.3.1. Same-day correlation analysis

4.3.1.1 Relationship between well-being and external workload

A single significant relationship was found between same-day morning well-being and match external workload variables: a moderate negative correlation (*rho* = -0.50, p = 0.050) between soreness and average work rate occurred on Day 1 of the competition. All remaining relationships were classified as being negligible or weak, and non-significant.

4.3.1.2 Relationship between well-being and internal workload

A moderate negative and significant correlation (*rho* = -0.57, *p* = 0.021) existed between motivation and internal workload on Day 1 of the competition. On Day 4 (semi-final), there was a moderate positive association between morning soreness scores and match sRPE (*rho* = 0.54, *p* = 0.032), while on Day 5 (final), a similar relationship was evident for stress and match-associated sRPE (*rho* = 0.52, *p* = 0.038). All other correlations showed negligible or weak, non-significant relationships between morning well-being scores and subsequent internal workload variables on the same day.

4.3.1.3 Relationship between external workload and internal workload

Significant relationships were consistently evident between match-associated external workload and internal workload variables on the same day. Total distance covered during the match showed a significant ($p \leq 0.001$) strong to very strong positive correlation (*rho* = 0.74 – 0.92) with player match time on all five days of the tournament. On Day 4 (semi-final), TD had a moderate positive correlation (*rho* = 0.51, *p* = 0.042) with sRPE score for the match. In addition, TD and estimated internal workload were positively correlated on Day 1, Day 3, Day 4, and Day 5 in the form of moderate (*rho* = 0.68, *p* = 0.004), strong (*rho* = 0.72, *p* = 0.001), very strong (*rho* = 0.91, $p < 0.001$), and strong (*rho* = 0.84, $p < 0.001$) correlations, respectively. Conversely, average work rate during the match showed moderate negative associations with player match time on Day 1 (*rho* = -0.55, *p* = 0.027), Day 3 (*rho* = -0.64, *p* = 0.008) and Day 5 (*rho* = -0.68, *p* = 0.003). Average work rate also showed moderate negative correlations with internal workload on Day 1 (*rho* = -0.55, *p* = 0.027), Day 2 (*rho* = -0.53, *p* = 0.036) and Day 5 (*rho* = -0.69, *p* = 0.003). Relationships between both high-intensity distance (HID) run or average high-intensity work rate and all internal workload variables showed only negligible or weak, non-significant correlations within all match days.

4.3.2 Preceding day-to-subsequent day correlation analysis

4.3.2.1 Relationship between external workload and well-being

A limited number of significant relationships existed between variables of match external workload and well-being scores reported on the subsequent day during the early stages of the tournament. A moderate negative correlation (*rho* = -0.51, *p* = 0.042) was found between TD on Day 1 and fatigue scores on Day 2, as well as between TD on Day 2 and stress score on Day 3 (*rho* = -0.50, *p* = 0.048). However, several significant relationships existed between some external workload variables in the final match and well-being scores on the day after the tournament. Average work rate on Day 5 and fatigue on Day 6 showed a moderate positive correlation (*rho* = 0.65, *p* = 0.007). Strong positive correlations were demonstrated between both HID and average high-intensity work rate on Day 5 and fatigue (*rho* = 0.70, *p* = 0.003 and *rho* = 0.88, *p* < 0.001 respectively) and total well-being (*rho* = 0.61, *p* = 0.012 and *rho* = 0.70, *p* = 0.002 respectively) on Day 6. All remaining correlations were non-significant and categorised as either negligible or weak.

4.3.2.2 Relationship between internal workload and well-being

Only post-match sRPE score on two of the five match days was significantly associated with well-being variables the following day in isolated cases. Day 3 sRPE was inversely related to Day 4 fatigue (*rho* = -0.50, *p* = 0.049) and sleep quality (*rho* = -0.67, *p* = 0.004) scores, while Day 4 sRPE showed a similar association with motivation (*rho* = -0.54, *p* = 0.032), but a moderate positive correlation with soreness (*rho* = 0.68, *p* = 0.004) on Day 5. No significant correlations were found between player match time or overall internal workload in matches and subsequent-day well-being scores throughout the tournament, with all relationships classified as either negligible or weak.

4.4. Differences analysis

This section reports on the significance (*p*-value), standardised magnitude effect size, ES), and accompanying 95% confidence interval (CI) of changes in well-being, external workload and internal workload observed over the course of the competition.

4.4.1 Well-being

Changes in total well-being and subscale scores are presented in Figures 4.1 and 4.2. Several significant differences in daily well-being scores were observed over the course of the tournament. Fatigue scores were moderately higher (ES = 0.77, *p* =

0.029) on Day 6 [4.0 (3.0 - 4.3) AU] than on Day 2 [2.0 (2.0 - 3.0) AU] (Figure 4.2 A). Energy level scores on Day 6 were higher (i.e. worse) compared to Day 2 (ES = 0.80, p = 0.015), Day 3 (ES = 0.81, p = 0.015), Day 4 (ES = 0.80, p = 0.015), and Day 5 (ES = 0.77, p = 0.029) (Figure 4.2 B). Stress scores were moderately higher on Day 5

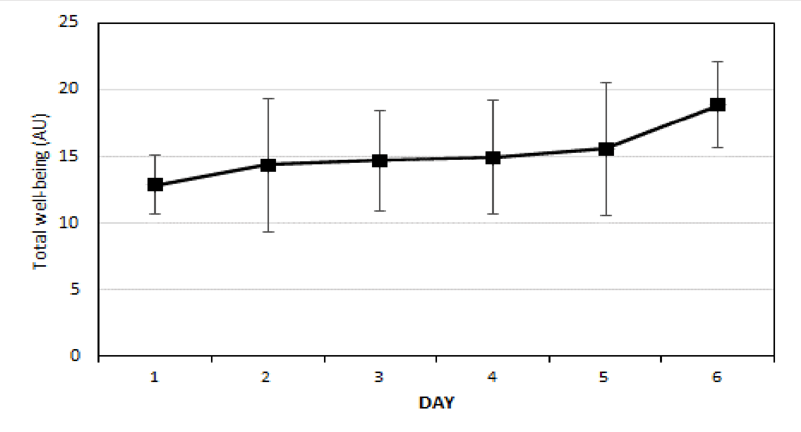

Figure 4.1: Daily changes in Total well-being by university female hockey players (n=16) during a congested competition period. All data represented as median (IQR).

(final) than on Day 1 (ES = 0.78, p = 0.029) and Day 3 (ES = 0.78, p = 0.029), and higher than on Day 2 (ES = 0.80, p = 0.015) (Figure 4.2 C). Stress scores on Day 6 were lower (ES = 0.83, p = 0.007) than on Day 5. Motivation scores on Day 6 were higher (i.e. worse) than on Day 1 (ES = 0.83, p = 0.007), Day 4 (semi-final, ES = 0.77, p = 0.030), and Day 5 (final, ES = 0.80, p = 0.015) (Figure 4.2 D). Soreness scores on Day 6 (3.0, IQR = 2.8-4.0 AU) were moderately higher (0.71 *ES*, p = 0.027) than on Day 1 (2.0, IQR = 1.0-2.3 AU) (Figure 4.2 F). No significant daily differences in sleep quality were evident (Figure 4.2 E). The total well-being score did not change significantly during the tournament (Figure 4.1), with all effects categorized as either trivial (ES < 0.1) or small (ES 0.2-0.4).

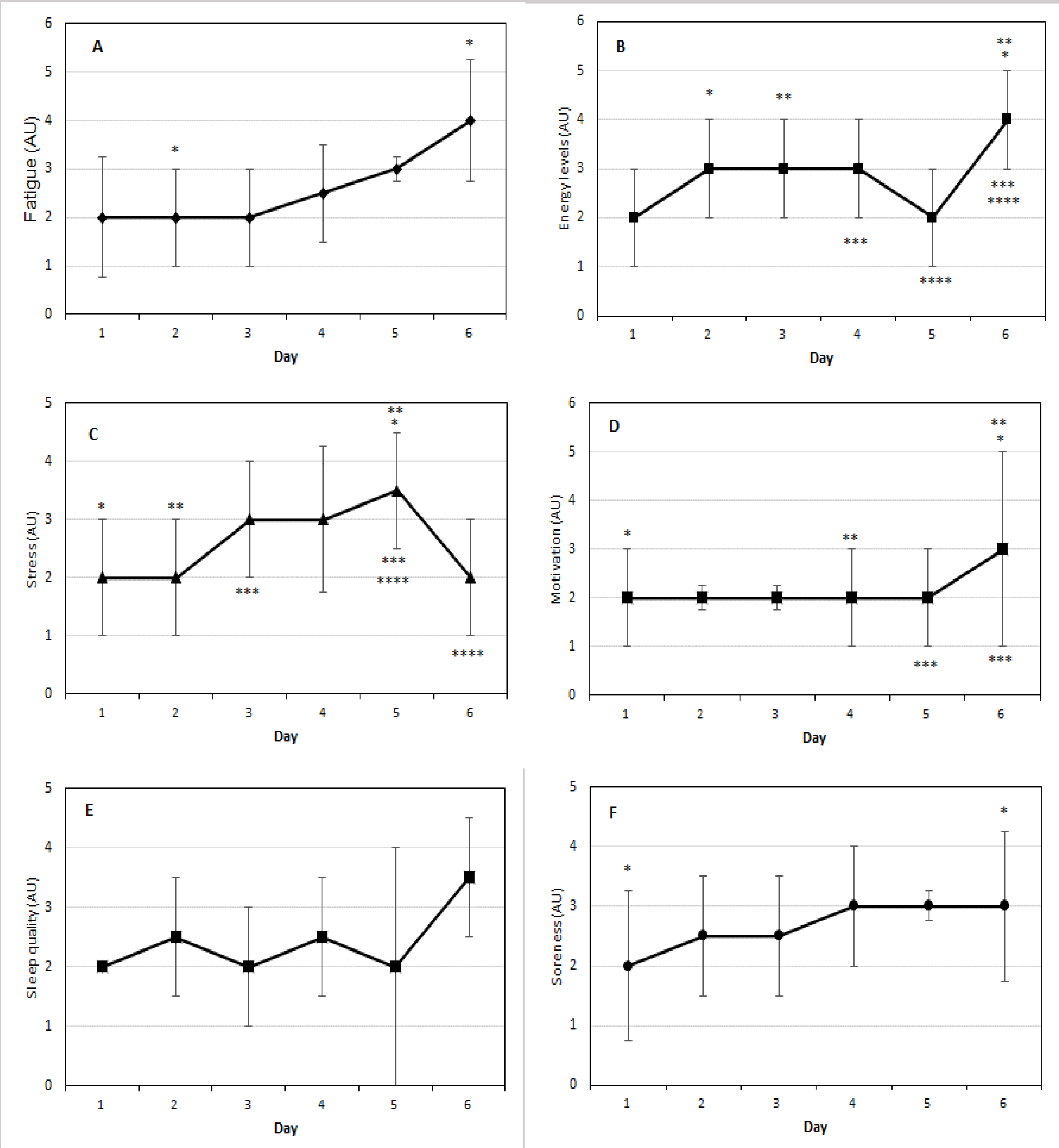

Figure 4.2: Daily changes in fatigue (A), energy Levels (B), stress (C), motivation (D), sleep quality (E) and soreness (F) by university female hockey players (n=16) during a congested competition period. Pairs of symbols (*,**,***,****) represent scores on different days of the competition that demonstrated moderate (ES = 0.5-0.7) to large (ES = 0.8-1.2) effect sizes that occured between each pair. All data represented as median (IQR).

4.4.2 External workload

Similar scores of TD in matches were recorded throughout the competition, as displayed in Figure 4.3. Scores of TD, HID, average work rate, and average high-intensity work rate demonstrated no significant daily differences through the tournament (Table 4.3). All external load variables showed only trivial or small magnitudes of change during the course of the tournament.

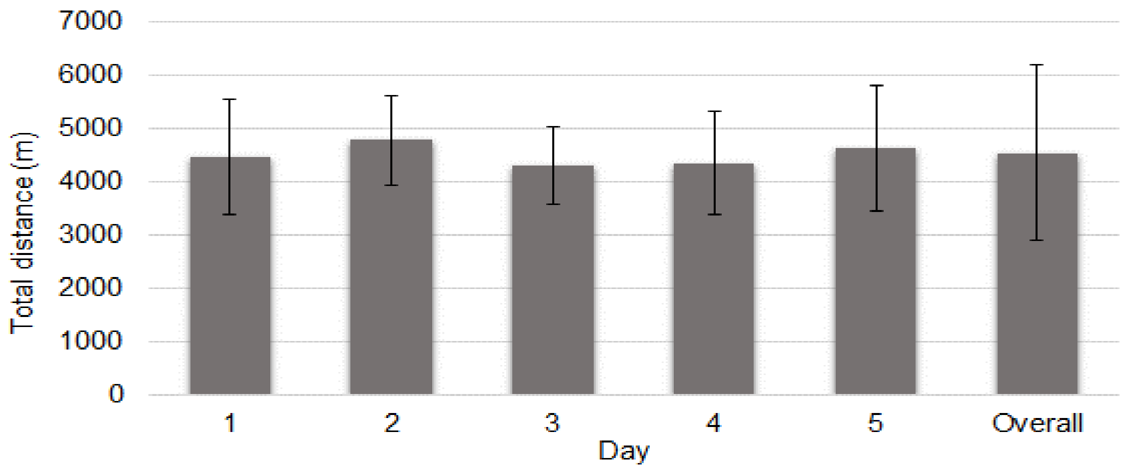

Figure 4.3: Total distance covered in each daily match by university female hockey players (n=16) during a congested field hockey competition period. All data represented as median (IQR).

4.4.3 Internal workload

There were no significant daily differences in player match time throughout the tournament (Table 4.4). As shown in Figure 4.4, internal workload tended to increase through the course of the tournament, but daily differences were not significant, and represented only trivial or small magnitudes of change.

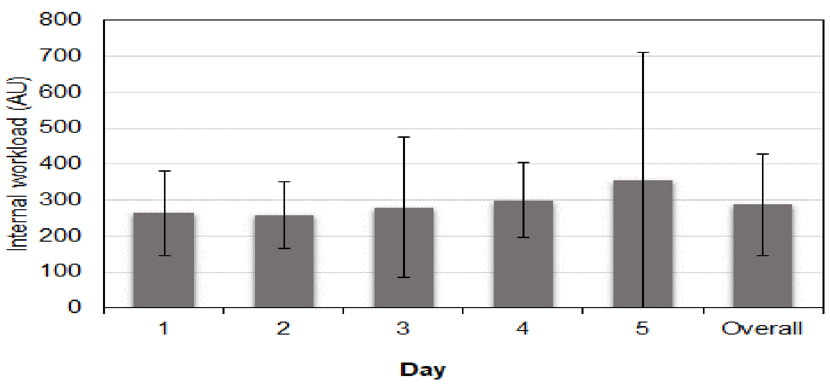

Figure 4.4: Changes reported in internal workload (AU) by university female hockey players (n=16) during a congested field hockey competition period. All data is presented as median (IQR).

4.5 Summary

A principal observation in these results is that well-being subscale scores and internal workload tended to progressively increase (worsen) during the course of the competition. By contrast, external workload variables fluctuated but did not change significantly between match days. In the correlation analysis, the overall finding was that limited moderate-to-large significant relationships existed between variables from different athlete monitoring categories within the same day, and over consecutive days of competition. The strongest and most consistent significant correlations occurred between two measures of external load (TD and average work rate), match playing time, and internal workload. Isolated significant preceding day-to-subsequent day relationships existed between external workload variables (TD, HID, average work rate, average high-intensity work rate) and some well-being variables (fatigue, stress and total well-being). As far as the differences analysis is concerned, the main finding was that moderate-to-large significant changes occurred in most (fatigue, energy levels, soreness and stress) but not all (sleep quality and motivation) well-being measures through the course of the competition, with the largest changes evident after the tournament was completed.

Chapter 5

Discussion

5.1 Introduction

The current study investigated both the day-to-day and cumulative effects of a congested competition period on measures of physical demand and well-being in university-level female field hockey players. The primary findings of this study were: 1. during the tournament, only one out of six well-being subscales (stress) changed (increased) significantly; 2. on the day after the tournament, four well-being subscales (fatigue, energy levels, motivation and soreness) were significantly worse and one subscale (stress) was significantly better than at least one tournament match day; 3. total well-being score did not change significantly during, or on the day after, the tournament; 4. there were non-significant fluctuations in match running performance and a non-significant rise in internal workload over the course of the tournament; 5. significant correlations were consistently found between external and internal workload variables on match days, while the majority of correlations between well-being and subsequent workload scores on match days were trivial to weak and non-significant; and 6. only two match workload variables (TD and sRPE) showed significant correlations with next-day well-being subscales, principally fatigue, on some tournament match-days, but most external workload metrics in the final match were associated with fatigue and total well-being scores the day after the tournament.

5.2 Well-being scores and workload during the tournament

Athlete self-reported well-being measures are commonly recorded when monitoring the response to training and competition workload (Taylor et al. 2012; Saw et al. 2015; Thorpe et al. 2017; Wellman et al. 2019). Interestingly, we observed that on Day 5, i.e. the morning of the tournament final, the highest score for stress [3.5 (3.0 – 4.0) AU] was reported along with, up until that point, the highest fatigue [3.0 (2.8 – 3.0) AU] and soreness [3.0 (2.8 – 3.0) AU] scores. It can be argued that elevated stress may be expected in athletes before a decisive event (McGuinness et al. 2018) and that, in this group of athletes, the coexistence of elevated fatigue and soreness was not significant, and did not compromise performance, since they won the tournament. In comparison, McGuinness et al. (2018) reported high levels of fatigue and stress throughout the course of an international competition in a team of elite female hockey players who failed to progress past the quarter-final stage. Thus, it may be that consistently elevated levels of fatigue and stress throughout the course of a tournament may be detrimental to performance, while elevations in these well-being subscales before a decisive match may not be reflective of compromised performance capability. Alternatively, these results may suggest there is little, if any, clear association between prior self-reported well-being scores and subsequent competition physical workload or performance capability (see Section 5.3).

To more representatively describe the nature of the well-being response to the tournament, well-being scores were obtained on the morning after the final match day (i.e. Day 6). As is common in many team sports, university-level competitions are associated with post-victory celebrations (Ransdell, Hildebrand, Spear & Lucas 2007) that can be expected to impact on the well-being of athletes and that may pose a risk to their physical recovery and health in general (Barnes, 2014). Perhaps as expected, fatigue, energy levels, motivation, and sleep quality scores were highest (worst) on Day 6 (i.e. the day after the team's tournament victory, as presented in Table 4.2), and were reflected in the high total well-being score [19.5 (17.0 – 20.3) AU]. By contrast, soreness scores were similar to Day 5, while stress scores were as low as observed in the early days of the tournament. The poor fatigue, energy levels, motivation and sleep quality scores at the end of the tournament could be attributed to post-victory euphoria and celebrations and accumulated fatigue (Soligard et al. 2016). The low stress scores could be attributed to the general sense of relief experienced after the completion of competition. These findings highlight the importance of both regular assessment of athletes' well-being before, during and after competition, and the monitoring of subscales of well-being as opposed simply a total well-being rating. To the authors knowledge this is the first study to report post-tournament well-being responses within field hockey.

Monitoring external workload in the form of match running performance by means of GPS wearable technology is well established in field-based team sports (Ihsan et al. 2017; Malone et al. 2017; McGuinness et al. 2017; McGuinness et al. 2018; Wellman et al. 2019). In comparison to our results for TD [4,545 (3,834 - 5,305) m], similar TD covered during match-play were observed by McGuinness et al. (2018) in elite female hockey players (4,847 ± 583 m). In comparison, other studies (McGuinness et al. 2018; McGuinness et al. 2017) observed considerably higher TD scores (5147 ± 628 m and 5558 ± 527 m respectively). The median (IQR) HID (i.e. >16 km.h^{-1}) for the current study was 383 (257 – 538) m. Findings of McGuinness et al. Mc Guinness et al. (2019) (580 ± 147 m) and McGuinness et al. (2017) (589 ± 160 m) indicated considerably higher HID covered by elite female hockey players during competitive match-play. In a study conducted by McGuinness et al. (2018) HID was as high as 753 ± 33 m.

The current study observed scores for average work rate of 116.8 (104.0 - 123.1) m·min^{-1} during matches. Similar findings were reported by McGuinness et al. (2018), (113 ± 8.9 m·min^{-1}). However, average work rate reported by McGuinness et al. (2019) mean ± SD TD (127.6 ± 15.6 m·min^{-1}) and McGuinness et al. (2017) (125 ± 23 m·min^{-1}) were higher than we observed. Average high-intensity work rate was [median (IQR)] 11.1 (5.8 - 14.9) m·min^{-1} in the current study. Scores of average high-intensity work rate reported in studies by McGuinness et al. (2019) (15.3 ± 6.0 m·min^{-1}) and McGuinness et al. (2018) (16.4 ± 5.3 m·min^{-1}) were higher, while McGuinness et al. (2017) observed an average high-intensity work rate of similar magnitude to the current study (13.0 ± 4.0 m·min^{-1}).

Comparisons of external workload with other studies on female hockey players should consider the level of the players and the nature of the competition period employed. In a study by Ramos, Nakamura, Penna, Mendes, Mahseredjian, Lima, Garcia, Prado and Coimbra (2019) on national female soccer players of varying age groups (u15, u17, u20 and senior level) during a training camp, measures for anthropometry and physical performance were carried out (Ramos et al. 2019). Comparisons between age groups, within each age group, and between non-selected and those selected for the team representation were conducted (Ramos et al. 2019). Results indicated a gradual improvement in physical characteristics (speed, lower body explosive power and aerobic capacity) as the players' biological ages (and one would imagine their player age) increased (Ramos et al. 2019). In addition to these findings, players exhibiting higher intermittent aerobic capacity had an increased likelihood of being selected into national teams. Thus, as players progress in biological age, better/improved results for physique and physical performance should be observed. Studies by McGuinness et al. (2018) and McGuinness et al. (2019) were carried out on elite international female hockey players. In contrast to the current study which recorded a mean (SD) playing age of 20 ± 2 y, both studies by McGuinness et al. (2018) and McGuinness et al. (2019) recorded a higher average player age of 23 ± 3 y. Therefore, it is suggested that older and more experienced athletes, playing at a higher competitive level, may possess greater physical performance characteristics, and attain/tolerate higher external workloads, in comparison to the values recorded for the university-level players in the current study. In addition, the present study also differs to that of McGuinness et al. (2018) in that the overall duration of their tournament was 16 days, during which only seven matches were played. The congestion and density of the competition format in the current study restricted the amount of recovery time that was available between matches. The reduced recovery time between matches may have led to reduced external workload. Other possible reasons for differences in findings in external workload and match running performance variables of the current study compared to others conducted on female hockey players can be coach-specific substitution rotation strategies, differing tournament rules, as well as characteristics unique to individual players and to the team as a whole (Ihsan et al. 2017; McGuinness et al. 2018; Mc Guinness et al. 2019).

The inconsistent nature of scores for TD, average work rate and average high-intensity work rate measured on each day of the congested competition period may be due to several factors. Opponents and team ranking would determine the intensity and nature of match-play (White & MacFarlane, 2015), individual traits or experiences may determine the effort each player is prepared to put into the match (Saw et al. 2015), and the degree of fan support and environmental discomfort (weather conditions) may influence external workload variables (Saw et al. 2015; Ihsan et al. 2017). These factors cannot be controlled for and therefore many research designs steer clear of the perturbations of competition periods (Saw et al. 2016) and rather focus on the training demands incurred during planned practice sessions in team sport athletes.

Internal workload monitoring in team sport athletes is commonly conducted using the session rate of perceived exertion (sRPE) method (Foster et al. 2001; Haddad et al. 2017; McLaren et al. 2017). Compared to the typical internal workload for each match observed in the current study [287 (214 – 355) AU], higher workloads (350 ± 58 AU) were reported by McGuinness et al. (2018) over a congested competition period in elite female hockey players. Due to the formula used to calculate internal workload, it follows that player match time, or exposure to match-play, will significantly influence internal workload. The median (IQR) player match time in the current study [39.1 (32.9 - 47.6) min] was considerably lower than typical values reported by McGuinness et al. (2018) (45.9 ± 6.2 min). In contrast to McGuinness et al. (2018), another study by McGuinness et al. (2019) reported player match time scores more similar to this study (38 ± 8 min). The match-play time afforded to each player is dependent on numerous factors including tactics, tournament rules and rotational substitution strategies (Ihsan et al. 2017). Therefore, it is to be expected that scores reported for internal workload may differ between research studies incorporating different teams of players, level of players, coaching staff, and tournament formats (Ihsan et al. 2017).

The descriptive results of the current study give practitioners valuable insight into the workload demands and well-being responses of university female student field hockey players during congested competition periods against the background of limited literature available in this field. The external and internal workload metrics observed in the current study were generally lower than those reported for higher level female hockey players (McGuinness et al. 2017; McGuinness et al. 2018; Mc Guinness et al. 2019), while the well-being responses reported were higher (worse) than reported by those researchers. Results from the current study depicted in Table 4.1 represent lower match running demands (McGuinness et al. 2017; McGuinness et al. 2018; Mc Guinness et al. 2019), lower internal workload scores (McGuinness et al. 2018) and higher (worse) well-being (McGuinness et al. 2018) scores compared to other studies on elite female hockey players.

5.3 Relationship between well-being and workload during the tournament

Studies by McGuinness et al. (2018) and Ihsan et al. (2017) over congested competition periods in elite female and male hockey players respectively, reported significant positive relationships between match running performance variables and same-day pre-match scores of total well-being (Ihsan et al. 2017) muscle soreness (McGuinness et al. 2018) and sleep quality (McGuinness et al. 2018). In concurrence with the current investigation, a study by Ihsan et al. (2017) investigated the relationships between athlete well-being reported prior to match play and match running performance in elite male hockey players during a congested competition.

When match running performance variables were normalised to player match time and sRPE, very strong inverse relationships existed between changes in well-being scores (higher scores reflective of worse well-being) and changes in both TD (*r* = -0.95, *p* = 0.003) and HID (*r* = -0.95, *p* = 0.004) throughout the competition period (Ihsan et al. 2017). Similarly, McGuinness et al. (2018) reported that an adverse change in daily well-being subscales of muscle soreness and sleep quality were associated with lower scores for player HID on the same day in female field hockey players during a congested international tournament. Furthermore, a study investigating the relationship between athlete well-being reported prior to measurements of match running performance during match-play in elite male football players during a competitive season, showed that daily player well-being worsening by a z-score of 1 or more was associated with a decrease in high-speed running performance variables of up to nine percent (Malone et al. 2018). In contrast to the studies above, the current study investigated the association between match workload indices and same-day morning well-being scores, rather than change scores. This analysis yielded only a single moderate significant relationship (*r* = -0.50, *p* = 0.050) between self-reported soreness and average work rate on Day 1 of the competition, in that soreness was inversely associated with average work rate. It may be that well-being score changes, rather than well-being scores per se, are more valuable to track in attempting to ascertain player external workload capacity during team-sport tournaments.

In athlete monitoring, both well-being (Taylor et al. 2012; Saw et al. 2015; Thorpe et al. 2017; Wellman et al. 2019) and internal workload (Drew & Finch, 2016; McLaren et al. 2017) assessment are well established. However, literature investigating relationships between these measures requires further attention (Clemente et al. 2017). The current study found several significant relationships between well-being variables and same-day internal workload experienced in the subsequent match. On Day 1 of the tournament, individuals with lower motivation tended to demonstrate lower post-match internal workload scores (*r* = -0.57, *p* = 0.021). On Day 4 and Day 5, individuals who scored higher on morning soreness and stress, respectively, tended to report a higher post-match sRPE (*r* = 0.54, *p* = 0.032; *r* = 0.52, *p* = 0.038). Only in isolated cases one may speculate that individuals who did not feel highly motivated also attained/tolerated lower workloads during the subsequent match, while individuals who felt more sore and stressed on the morning before a match, perceived the match as more demanding.

Clemente et al. (2017) provide support for the tenuous relationship between pre-match well-being and internal workload. In their investigation of relationships between well-being and internal workload in elite male soccer players during a less versus more congested performance schedule, such as when one or two matches were played within a typical training week, trivial ($r \leq 0.1$) to small ($0.1 < r \leq 0.3$) inverse relationships between well-being variables and subsequent internal workload scores were demonstrated in both microcycle periods (1-game and 2-game weeks), with stronger correlations evident during 2-game microcycles in comparison to 1-game microcycles (Clemente et al. 2017). During 1-game microcycles, pre-match stress and sRPE showed a trivial (r = -0.080) relationship; during 2-game microcycles, small negative relationships were found between pre-match soreness (r = -0.156), sleep (r = -0.109), stress (r = -0.188), fatigue (r = -0.225) and total well-being (r = -0.238) with internal workload (Clemente et al. 2017). By contrast, Moalla et al. (2016) reported that higher (adverse) scores of well-being subscales were associated with higher (unfavourable) subsequent internal workload scores. In their study on professional soccer players engaged in a training over a period of 16 weeks, significant ($p < 0.01$) moderate ($0.3 < r \leq 0.5$) positive relationships for pre-match sleep (r = 0.23), stress (r = 0.30), fatigue (r = 0.48), soreness (r = 0.48) and total well-being (r = 0.47) with internal workload were demonstrated.

In summary, this study found very little evidence of the predictive value of morning well-being scores for subsequent external or internal match workload on the same day during a tournament. In early rounds, better scores on soreness and motivation may be related to higher average work rate and internal workload, while in the final rounds, worse soreness and stress scores may be reflected in higher internal workload following matches, but significant correlations are isolated and not strong.

Monitoring internal training or competition workload through the sRPE-method is widely accepted and utilised in team sports (Drew & Finch, 2016; Foster et al. 2001; Haddad et al. 2017; McLaren et al. 2017). Previous research on internal workload measures has demonstrated strong positive relationships with external workload measures of TD (r = 0.79; 90% CI) during both match-play and training sessions

(McLaren et al. 2017). The current study observed moderate (Day 1, $r = 0.68$, $p = 0.004$) to very strong (Day 4, $r = 0.91$, $p < 0.001$) positive relationships between TD and internal workload. Interestingly, significant moderate inverse relationships between internal workload ($r = -0.53$ to -0.69, $p \leq 0.036$) and average work rate were reported. Possible reasons for these relationships demonstrated between external workload (TD) and internal workload, could be the formula used which incorporates player match-time, which itself also demonstrated several strong to very strong consistent relationships with TD throughout the course of competition. This suggests that player match time may be a simple and practical method of quantifying workload worth investigating.

The findings of the study are in agreement with previous research which supports the sRPE rating as a valuable tool for gaining insights into external workload (Foster et al. 2001; Halson, 2014; McLaren et al. 2017). The use of the sRPE rating, as opposed to the calculation of internal workload by means of the sRPE-method, is suggested when the session duration is not fixed or standardised across players (Malone et al. 2018). During match-play, tactics or rotation strategies may influence session duration thereby distorting the internal workload score. Therefore, in circumstances where the objective measurement of external workload is not possible, or when frequent exercise testing is not practical, monitoring of sRPE is recommended.

Overall, we found consistent and strong evidence that the external workload variable TD is reflective of playing time (i.e. more time spent on the field gave players greater opportunity to accumulate TD independent of the running speed or associated intensity), and is associated with internal workload on most, if not all, match days of a tournament. These results support the use of player match time and the sRPE-method of quantifying workload in female university hockey players during a congested tournament as means of monitoring and managing player workload. Perhaps unsurprisingly, this study found that players with shorter match time and lower overall internal workloads tended to return higher average work rates during most matches of the tournament. There were no substantive relationships between the distance or average work rate of high-intensity running in any match and the playing time, sRPE or internal workload experienced for that match in our study. These findings support the use of player rotation strategies based on individual player match time as an effective means of player management.

High sensitivity of athlete well-being to workload changes have been demonstrated during periods of training (Saw et al. 2015) and during match-play over a competitive season (Gastin, Robinson & Meyer, 2013; Wellman et al. 2019). Research exploring relationships between acute increases in training workload and subsequent athlete well-being have yielded positive dose-response relationships (i.e. increases in training workload are generally associated with more adverse subsequent well-being scores) for the following subscales: total well-being (Saw et al. 2015; Soligard et al. 2016), fatigue (Saw et al. 2015; Soligard et al. 2016; Thorpe et al. 2017; Wellman et al. 2019), stress (Saw et al. 2015; Wellman et al. 2019) and soreness (Drew & Finch, 2016; Wellman et al. 2019). Studies carried out by Gallo et al. (2016) and Wellman et al. (2019) investigated relationships between external workload in the form of match running performance and subsequent self-reported well-being in Australian football players and collegiate level football players, respectively. In both studies, players who recorded higher match running performance during match-play tended to report significantly worse well-being scores on the day thereafter. The results of the current study only partially support previous research. Limited moderate (r = 0.40 to 0.69) to strong (r = 0.70 to 0.89) relationships were evident between workload (external or internal) on the preceding day and well-being on the subsequent day. Specifically, moderate positive correlations were demonstrated between TD (Day 1) and fatigue (Day 2), TD (Day 2) and stress (Day 3), and average work rate (Day 5) and fatigue (Day 6). Strong positive correlations were demonstrated between HID (Day 5) and both fatigue and total well-being scores on Day 6. Thus, several significant ($p < 0.05$) relationships occurred during the competition period between match running performance on the preceding day to well-being on the subsequent day.

In summary, we observed very few associations between any match-derived external or internal workload variable and well-being scores reported on the morning of the subsequent day during the course of tournament play (Day 1 to 5). Those present were typically moderate in strength and inverse in nature. Only sRPE scores from the semi-final match were proportionally related to soreness scores the following day, and again, moderately in strength. These results suggest caution in interpreting morning well-being scores as reflective of TD, average work rate, high-intensity distance or work rate, playing time or match workload from the previous day during a congested tournament. However, moderate to strong associations in this study suggested that higher average work rate and high-intensity distance and work rate in the final match (Day 5) was reflected as higher (worse) fatigue and total well-being scores on the day after the tournament (Day 6).

5.4 Changes in well-being and workload during the tournament

It has been previously established that physical demands imposed on athletes through participating in either training or competition is associated with a change/progression toward more adverse scores of self-reported well-being, particularly fatigue (Saw et al. 2015; Soligard et al. 2016). In severe cases, where high training and/or competition workloads are experienced with inadequate athlete recovery or workload management, athletes are placed at higher risk of developing excessive fatigue, and overreaching or overtraining (OTS) symptoms, or injury (Saw et al. 2015; Soligard et al. 2016). Thus, the ability to detect changes in responses to workload assessed from different perspectives is imperative in supporting optimal performance and reducing the likelihood of illness or injury. While scores in well-being measures in the current study showed trends toward increasing (worsening) over the course of the tournament proper (Figure 4.1 and Figure 4.2), changes were only trivial to small and non-significant between match days. The exception was self-reported stress scores, which were significantly higher on the day of the final match than on earlier tournament days, and then significantly lower on the day after the tournament. Significantly worse scores were observed for fatigue, energy levels, motivation, and soreness on the day after the tournament (Day 6) compared to one or more days during the competition.

The findings of lower well-being scores following the tournament in the current study may be attributed to accumulated fatigue during the week, owing to the depletion of muscular energy substrate stores or muscle damage (Ihsan et al. 2017). In agreement with the previously mentioned statements, the current study observed moderate increases (ES = 0.71, $p = 0.027$) in soreness scores between Day 1 (2.0, IQR 1.0 - 2.3 AU) and Day 6 (3.0, IQR 2.8 - 4.0 AU) (Figure 4.2 E), moderate increases (ES = 0.77, $p = 0.029$) in fatigue scores between Day 2 (2.0, IQR 2.0 - 3.0 AU) and Day 6 (4.0, IQR 3.0 - 4.3 AU) (Figure 4.2 A), and large reductions (ES = 0.80, $p = 0.015$) in energy levels between Day 2 (3.0, IQR 2.0 - 3.0 AU) and Day 6 (4.0, IQR 3.0 - 4.0 AU) (Figure 4.2 B).

In contrast to McGuinness et al. (2018), who reported fluctuations of responses in total well-being, fatigue and soreness, the present study showed a gradual (non-significant) increase (worsening) of these specific variables through the course of the competition. McGuinness et al. (2018) showed favourable reductions of soreness scores prior to matches 4 (3.5 ± 1.0 AU; 12.3 % ES; 0.29 ± 0.36) and 6 (3.3 ± 1.2 AU; 9.7% ES; -0.22 ± 0.12) out of a total of seven matches, when compared to the first match of the tournament. A study conducted by Ihsan et al. (2017) supports the findings of the current study, in that scores of total well-being, fatigue and soreness increased adversely in elite male hockey players during a congested competition during which six matches were played over a period of nine days. Interestingly, in studies by Ihsan et al. (2017) and McGuinness et al. (2018), well-being responses demonstrated favourable changes as a likely result of recovery days included in the tournament schedule. In concurrence with the findings of the current study, Mendes et al. (2018) reported significant ($p < 0.05$) negative changes of well-being during congested (two or more matches) weeks when compared to regular (one match) or training weeks in elite male volleyball players over a competitive season.

Sleep quality scores in the current study varied little during the competition, showing no clear or significant trends (Figure 4.2 E). In contrast, McGuinness et al. (2018) reported a continuous decline in sleep quality in elite female hockey players throughout a competition period of 16 days. In addition to these findings, significant ($p < 0.05$) adverse changes in sleep quality were reported during congested weeks (McGuinness et al. 2018). The findings of the current study could be attributed to the variation in the time-of-day that matches were scheduled throughout the competition. Matches were scheduled in the morning, early or late afternoon, leading to different durations of recovery between matches on consecutive days that may potentially have contributed to variations in athlete perceptions of sleep quality over the course of the tournament.

In the current study, only player stress ratings showed significant changes during the tournament proper: stress scores were moderately to largely higher on the day of the final (Day 5) compared to the early rounds of the tournament (Days 1, 2 and 3), and to the day after the tournament (Day 6). It is suggested that, as the team under investigation succeeded and progressed over the course of the tournament, the increase in stress scores could be a result of an increased pressure and perceptual importance of match results. Mendes et al. (2018) demonstrated significant adverse changes in stress during congested weeks of competition in elite male volleyball players. Thus, during periods of congested fixtures athletes may experience increased stress and should be monitored and managed with due consideration (Mendes et al. 2018; Clemente et al. 2020).

In the current study, no significant changes were observed in measures for external workload, with scores fluctuating by a trivial to small extent throughout the competition (Table 4.3 and Figure 4.3). In contrast to findings by McGuinness et al (2018) who reported a considerable decline in average work rate (-9.5%, ES = 0.63 - 0.95) and average high-intensity work rate (-25%, ES = 0.13 - 0.63) between the first and last matches played, the current study found no significant changes in daily match running performance variables (TD, HID, average work rate and average high-intensity work rate) over the course of the congested tournament. Match running performance scores reported by Ihsan et al. (2017) concur with the current study in that no significant changes in scores were observed throughout a congested hockey tournament. The lack of change in team external workload metrics can – again - be attributed to various factors such as the ability and nature of play of opponents, team tactics, recovery time between matches, player rotation strategies, and individual playing traits or experience (Ihsan et al. 2017; McGuinness et al. 2018; McGuinness et al. 2019). Collectively these factors may determine the external workload each player undertakes in the match and can be further influenced by the extent of fan support and weather conditions (Ihsan et al. 2017; Saw et al. 2015).

The effects of congested competition periods on internal workload have not been extensively explored (Clemente et al. 2017). Although no significant changes in internal workload measures were observed in the current study, scores of internal workload tended to increase steadily throughout the competition (Figure 4.4) from Day 1 [264 (208 – 325) AU] to Day 5 [355 (192 – 546) AU]. These findings differ somewhat to those by Ihsan et al. (2017) and McGuinness et al. (2018). McGuinness et al. (2018) reported a considerable increase in internal workload (sRPE x player match time) scores after the second game of the tournament. Following this spike, scores decreased and remained consistent for the rest of the competition (McGuinness et al. 2018). Ihsan et al. (2017) reported a steady increase in internal workload scores from games 1 to 3, followed by inconsistent scores in the remaining games 4 to 6. The trend for an increase in internal workload over the course of the tournament observed in the current study, could be due to the highly condensed competition schedule placing an unaccustomed and cumulative physical and mental demand on the players, resulting in rising perceptions of match effort (Figures 4.1 and 4.2).

Chapter 6

Conclusion and recommendations

6.1 Conclusion

From the results of the current study, it is evident that university female hockey players recorded lower match running performance demands than those experienced by elite international players during congested competition fixtures (McGuinness et al. 2017; McGuinness et al. 2018; McGuinness et al. 2019). Scores for player total well-being and subscales of fatigue, soreness and stress tended to worsen during the competition, but changes were trivial to small between match days. Significant correlations were consistently demonstrated between variables of external and internal workload on match days. Furthermore, several moderate-to-very strong predictive relationships were demonstrated between match running performance variables and subscales of well-being reported on the following day through the tournament.

Periods of training and competition that are characterized by a rapid or sporadic increase in acute workload – such as during congested competition fixtures – place athletes at higher risk of succumbing to illness and injury (Soligard et al. 2016). This emphasizes the need for optimal physical preparation and incorporation of recovery protocols (Jennings et al. 2012). Furthermore, the inability to optimize physical preparation and recovery based on the accurate monitoring of overall demand experienced by athletes, may place them at further injury risk or exacerbate their progression into adverse psychological (well-being) and physiological states (Soligard et al. 2016). This is even more evident in student-athletes given the unique demands of balancing academic, sporting and social environments. Although total well-being score, as derived from the summing of scores for the subscales of well-being, is commonly thought to reflect the overall state of readiness to perform, it may not be the most sensitive reflection of the physical and mental demands experienced by the athlete. Therefore, based on results of the current study the respective subscales of well-being (with specific reference to stress, soreness and fatigue) should be monitored during congested competition fixtures.

Even though support staff commonly assume that a high level of athlete well-being is required for athletes to perform successfully within competitive environments (Linqvist, 2011), there is a lack of evidence on the relationships between pre-match well-being and subsequent external workload in the form of match running performance. Previous research in team sports during various periods of training and competition reported strong relationships between high-intensity running workload and pre-session well-being subscales of fatigue and soreness (Gallo et al. 2016; Ihsan et al. 2017; Malone et al. 2018, Wellman et al. 2019). Findings from the current study indicate that relationships between pre-match well-being and match running performance were inconsistent and non-significant. However, there was a single exception to this statement which occurred during Day 1 where a significant moderate inverse relationship was demonstrated between soreness and average work rate. Therefore, players who reported higher soreness before the match performed at a lower average work rate in the match that day. Thus, monitoring overall pre-match well-being for the sole purpose of predicting/gauging physical performance during a field hockey match is not supported by the current study.

Several moderate-to-very strong predictive relationships between external workload and well-being reported on the subsequent day of competition were demonstrated, with special reference to the last day of the competition. These findings support findings of previous literature with regards to increases in external workload being strongly associated with a decline in athlete well-being after matches (Gallo et al. 2015; Malone et al. 2018; Wellman et al. 2019). Many competitive sports events competitions are marked by celebrations and/or routine practices following the last match (Ransdell et al. 2007). The current study found the highest (adverse) well-being scores on the morning following the last (victorious) game. Support staff and coaches should consider the combined effects that the competition event and post-competition activities may have on players, especially in the days immediately following congested fixtures, as this may require adjustments to training schedules, recovery routines, or travel schedules. It is imperative that interventions focusing on recovery (psychological and physiological) take place before student-athletes return to academic and sport commitments to avoid them progressing into poor health states or OTS. As outlined by Surujal et al. (2013), student-specific challenges include the maintenance of balanced schedules of academic and sports commitments, as well as cementing relationships with peers. In addition to the academic pressures that congested competitions may place on students, tournaments such as that of the current study generally take place during scheduled university recess periods, which would normally allow students to rest and recovery physically, mentally and emotionally.

Within the findings of the current study strong and significant relationships were observed for both sRPE scores and internal workload with TD, average work rate, and match time during the tournament. Other studies found similar results during training periods (Lockie et al. 2016; Malone et al. 2017; Wellman et al. 2019). Thus, results from the current study lend support to the notion that internal workload monitoring appropriately reflects external workload during congested competition without the need for constant, expensive or labour-intensive objective training load monitoring equipment.

6.2 Strengths of the study

The following factors could be considered as strengths of the current study:

- To the researchers' knowledge, this is the first study to investigate well-being and workload demands in a relatively homogenous population of young adult female student field hockey players.
- To the researchers' knowledge, the current study is the first to monitor and include post-tournament well-being scores.
- The study adds to the existing, fairly limited body of research on female athletes with regards to workload demands, well-being and athlete monitoring in team sports.
- The study adds to the sparse body of research on athlete monitoring during congested competition fixtures with special relevance to the responses of female student-athletes to inter-university tournaments.

6.3 Limitations of study

The following factors could be considered as limitations to the current study:

- Participants were limited to university female field hockey players, selected by the head coach to represent the respective university's first women's hockey team at the annual inter-university hockey tournament.

- The sample size was limited to 16 participants who play in outfield positions. This is generally considered a small sample size. However, this is in accordance with previous literature by (Lythe & Kilding, 2011; Jennings et al. 2012; McGuinness et al. 2018) and is a larger population than utilised for some studies published on team sport athletes (Ihsan et al. 2017; Thorpe et al. 2015; Fessi et al. 2018).

6.4 Practical recommendations

To improve the preparation and management of players, sport scientists and coaching staff should be educated on the demands that female university-level hockey players are exposed to during congested tournaments, as well as the differences that exist to that of elite female hockey players. These findings provide a platform for sport scientists and coaching staff to formulate specific preparation and in-competition player management strategies relevant to the demands faced by female university hockey players.

Performance demands of congested inter-university tournaments are unique with regards to the number of matches played in a short time period of time, often involving a match played every day, and limited recovery time available. In planning the preparation periods leading into such tournaments, it is imperative that support staff not only ensure that players are at an optimal state of physical readiness, but also have had sufficient exposure to periods of training mimicking the demands of these tournaments. It is also recommended that practitioners and coaches should devise and implement recovery strategies that are adaptable to the unique tournament schedule. In addition to this, it is suggested that recovery strategies should be adjusted to individual well-being and internal workload responses as well as match running performance.

Subjective variables that have shown high levels of sensitivity to external workload in the current study are internal workload, total well-being, fatigue and soreness, and should be implemented in athlete monitoring approaches during periods of competition. Monitoring the subscale of stress is not indicated during congested competition periods. It can be argued that elevated stress during competition is unavoidable and, in the current study, was not associated with workload demands.

Objective variables of match running performance including TD and average work rate demonstrated moderate to strong relationships with internal workload in this study and are well-established metrics for quantifying external workload. Although internal workload assessed using the sRPE-method is a useful tool in monitoring the perceived hardness of training and match-play, including scores of well-being and match running performance may lead to more effective workload demand interpretation and player management strategies (Ihsan et al. 2017).

Player rotation strategies are encouraged to assist in the management of fatigue during congested fixtures. However, decisions regarding these strategies and the implementation thereof should take a multi-factorial approach. This approach should encourage support staff and coaches to monitor all forms of workload (external and internal) and responses to workload (e.g. well-being scores).

It is suggested that an emphasis must be placed on the education of players and support staff on useful athlete monitoring practices based on research evidence. This should take the form of a holistic approach that places priority on the physical and sport-specific aspects, as well as the personal and psychosocial aspects student-athletes should expect leading into congested competition, in comparison to solely relying on player rotation, selection strategies, or reduced external workload measures. This is because timing of these tournaments at a university level are heavily influenced by and integrated into the academic and holiday calendar, which requires effective planning to be done well in advance for protect student athlete health and support performance. To ensure more effective means of athlete preparation, it is suggested that training periods or stimuli that reflect the unique match running performance demands of match play during congested competition be incorporated into training (McGuinness et al. 2018). This could be of benefit to avoid significant and unaccustomed spikes in training workload (McGuinness et al. 2018) that may disrupt player well-being, increase fatigue and increase risk of injury. Furthermore, customised sleep, nutrition and recovery routines should be investigated, and training programmes modified to allow sufficient tapering for athletes to arrive well rested on the first day of match-play.

6.5 Recommendations for future research

Due to the lack of literature investigating the subjective and objective workload demands of university-level female field hockey players during congested tournaments (Surujlal et al. 2013; McGuinness et al. 2018; Rabbani et al. 2018; Wellman et al. 2019), research adding to this field is recommended. Research can also be directed towards investigating the workload demands and well-being responses in university-level male field hockey players, as limited research is available (Surujlal et al. 2013; Ihsan et al. 2017; Rabbani et al. 2018; Wellman et al. 2019). Research involving more participants, leading to a bigger sample size is recommended. This however requires the collaboration of different teams or universities which could pose potential challenges including, but not limited to, refusal to share information and the difference in athlete monitoring tools at their disposal. McGuinness et al. (2018) reported adverse daily changes in pre-match well-being scales were associated with an adverse change (decline) in HID performed during match-play on the same day. In addition, Ihsan et al. (2017) reported pre-match well-being scores demonstrated significant negative relationships with several match running performance variables when normalised to player match time and sRPE values. As there is no other research available investigating pre-match well-being relationships with match running performance variables, further research replicating these methods (please refer to chapter 5.3) is encouraged to corroborate these results and better understand the significance and value of athlete workload and well-being monitoring in field hockey during congested tournaments.

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Appendix A: Data capture (online application): Daily Well-being Questionnaire

Test Athletes

Enter new Daily Check-In for Test2 Pretoria

On Date Thu, 29-11-2018 from 12:15 PM ▼ to 1:15 PM ▼

Daily Wellbeing

Please rate how you are feeling on each of the following items

Fatigue	○ Very Low	○ Low	○ Average	○ High	○ Very High
Energy Levels	○ Very Low	○ Low	○ Average	○ High	○ Very High
Stress	○ Very Low	○ Low	○ Average	○ High	○ Very High
Motivation	○ Very Low	○ Low	○ Average	○ High	○ Very High
Soreness	○ Very Low	○ Low	○ Average	○ High	○ Very High
Sleep Quality	○ Very Low	○ Low	○ Average	○ High	○ Very High
Sleep Hours					

Availability Check-In

The next question refers to your availability to participate in full prescribed training or competition in the last 24 hours, and how this may have been affected by injury or illness.

If your programme did not include training/competition in the last 24 hours but you are carrying an injury/illness, please respond to the questions as if you had been required to train/compete.

During the past 24 hours, which of the following best describes your status?
- ○ Fully available for training/competition without health problems
- ○ Fully available, but with an injury/illness
- ◉ Available for modified training due to injury/illness
- ○ Unavailable due to injury/illness

To what extent did you/would you have modified your training due to injury or illness during the past 24 hours?
- ○ No modification
- ○ Minor modification
- ○ Moderate modification
- ○ Major modification

To what extent did/would injury or illness have affected your performance during the past 24 hours?
- ○ No effect
- ○ Minor effect
- ○ Moderate effect
- ○ Major effect

To what extent have you experienced symptoms/health complaints during the past 24 hours?
- ○ No symptoms/health complaints
- ○ Mild symptoms
- ○ Moderate symptoms
- ○ Severe symptoms

Is the health problem referred to in the above questions an injury or illness?
- ○ Injury
- ○ Illness

Is this the first time you have registered this problem through the Daily Check-In? Yes, this is the first time ▼

The following errors need to be fixed before moving on:
- Fatigue is required
- Energy Levels is required
- Stress is required
- Motivation is required
- Soreness is required
- Sleep Quality is required
- Sleep Hours is required
- Is the health problem referred to in the above questions an injury or illness? is required
- To what extent did you/would you have modified your training due to injury or illness during the past 24 hours? is required
- To what extent did/would injury or illness have affected your performance during the past 24 hours? is required
- To what extent have you experienced symptoms/health complaints during the past 24 hours? is required

History For Daily Check-In

Daily Check-In – completed daily in the morning

PART 1: DAILY WELLBEING

Please **rate how you are feeling** on each of the following items.

Although some of the questions might appear similar, there are differences between them, and you should treat each one separately. The best approach is to answer each question fairly quickly. There are no right or wrong answers, and your first impression is usually the most accurate response.

Fatigue: Are you feeling tired, sleepy, worn out?

Energy levels: Are you feeling energetic, active, alert?

Stress: Are you feeling stressed, under pressure, having difficulty coping?

Motivation: Are you feeling motivated, eager?

Soreness: Are you experiencing muscle soreness, heaviness, stiffness?

Sleep quality: Are you falling asleep easily and not experiencing restlessness?

Note: Each question requires a response on a scale from very low to very high.

"Very high" indicates a worse condition for fatigue, stress and soreness but a better condition for energy levels, motivation and sleep quality

Sleep hours: The total number of hours of sleep you've had during the past 24 hours

(Grove et al., 2014, Main and Grove, 2009, Malone et al., 2018, McGuinness et al., 2018, Wellman et al., 2019).

Appendix B: Permission letter for UP student-athlete recruitment, TuksSport

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

TuksSport

25th June 2019

To Whom It May Concern:

RE: Permission for Study within TuksSport

This letter serves as confirmation that TuksSport, through my office, has been approached by the researcher requesting permission to approach our various TuksSport specific clubs for the purpose of the research stated below.

Title of Research: Training load and athlete well-being in university female hockey players during a congested tournament

Degree: MSc Hons (Sport Science)

Student: Mr. J. Swan (10230824)

We hereby grant permission for the researchers to approach the TuksHockey Club, as agreed upon with myself. We suggest that this drive is done through my office, so as to encourage the coaches participation and endorsement of the research. The request is that the findings of the research be provided to TuksSport and the TuksHockey club after assessment and on completion of the research.

At TuksSport, we are encouraging the practical research application into our club systems, which aligns with the University of Pretoria's 2025 strategic vision and plan and ultimately aid and enhance our sporting performances on the field of play.

Please feel free to contact me if you have any questions.

Yours Sincerely

Mr S. Ball

DEPUTY DIRECTOR: Coaching & Performance Management

Building and Room no: TuksSport Complex
University of Pretoria
PRETORIA 0002
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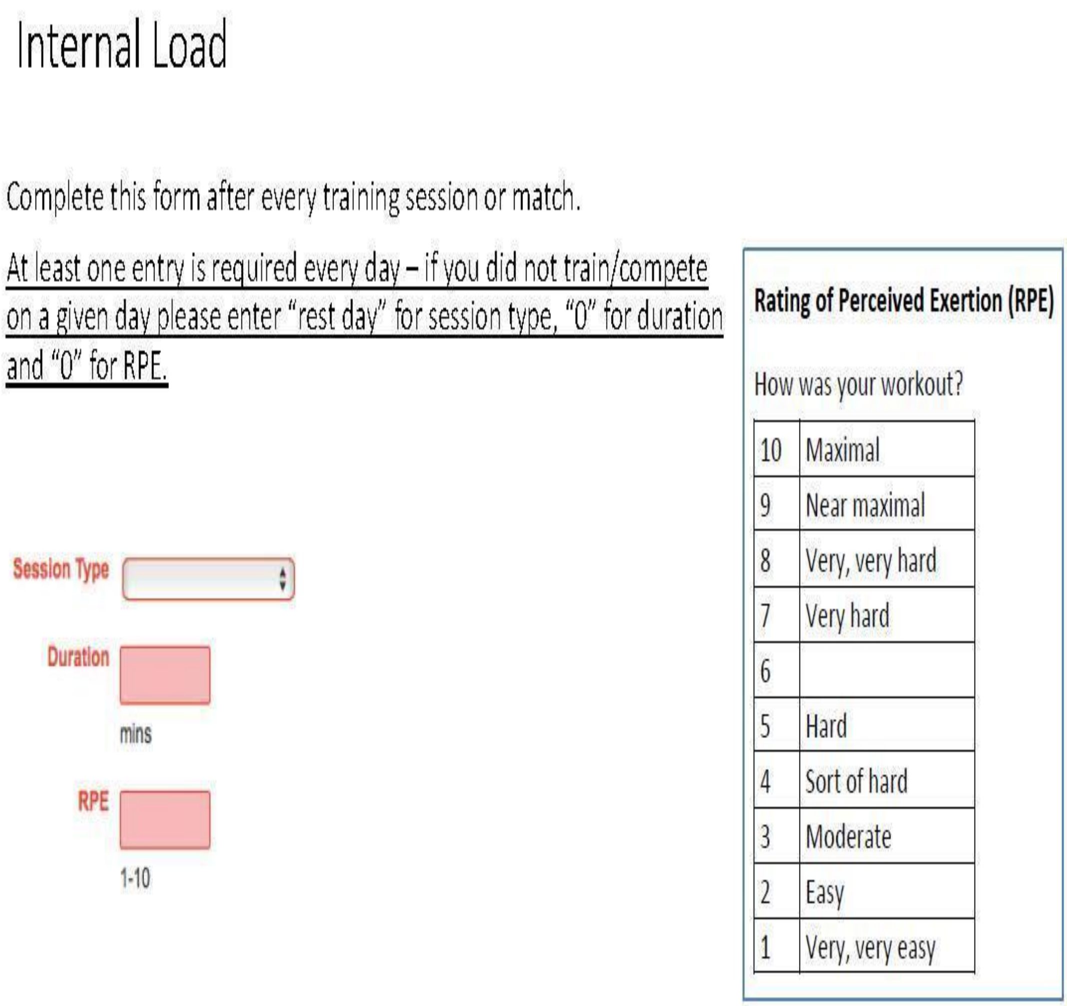
Appendix C: Data capture (online application): Daily Internal Workload Questionnaire



Internal Load

Complete this form after every training session or match.

At least one entry is required every day – if you did not train/compete on a given day please enter "rest day" for session type, "0" for duration and "0" for RPE.

Session Type

Duration

mins

RPE

1-10

Rating of Perceived Exertion (RPE)

How was your workout?

10	Maximal
9	Near maximal
8	Very, very hard
7	Very hard
6	
5	Hard
4	Sort of hard
3	Moderate
2	Easy
1	Very, very easy

(Drew & Finch, 2016; Foster et al. 2001; Gallo et al. 2016; Haddad et al. 2017, Ishan et al. 2017; McLaren et al., 2017; Malone et al. 2018; McGuinness et al. 2018;)

Appendix D: Statistician letter confirming support for the proposed analysis

8 April 2019

Prof M Kock
Chair: University of Pretoria, Faculty of Health Sciences Research Ethics Committee
University of Pretoria
PRETORIA, 0001

Dear Professor Kock,

RE: Statistical support for the research protocol entitled "Athlete well-being and internal workload associations with match running performance in university female field hockey players over a congested competition period" in partial fulfilment for the degree MSc Sport Science

I hereby confirm that I am aware of the project and that consultation had taken place with regard to the statistical analysis described in the research proposal. I support the statistical methodology.

Yours sincerely,

ANESU G KUHUDZAI
CHARTERED STATISTICIAN (ICCSSA-14ChM002)
Cell phone number: 078 768 9666
Email: gelfand9@yahoo.com

Appendix E: Participant Information and Informed Consent Form

Student athlete health, well-being and sports performance: A prospective study over 5 years

ADULT PARTICIPANT INFORMATION AND INFORMED CONSENT DOCUMENT

Introduction

You are invited to volunteer to participate in a research study. This leaflet is to help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions that are not fully explained in this leaflet, do not hesitate to contact the investigators.

The nature and purpose of this study

Researchers from the Sport, Exercise Medicine and Lifestyle Institute at the University of Pretoria will conduct a study entitled "Student athlete health, well-being and sports performance: A prospective study over 5 years". The study aims to identify factors that affect student athlete health (Illness, injury), well-being (psychological status), academic performance and sports performance.

Explanation of procedures to be followed

Your participation in this research study is entirely voluntary. A number of the components described below are part of the routine assessment and monitoring procedures for your sport. Should you agree to participate, you would be asked to give consent to participate in the following components of the study:

- Functional movement and musculoskeletal screening assessment. This is a series of tests to assess your movement quality, mobility and strength. The assessment will be completed 1 – 2 times per year by a sport scientist.
- Sport-specific physiological testing. Sport scientists conduct a series of tests to assess physiological components that are relevant to your sport, which may include body composition, flexibility, explosive power, muscular strength, muscular endurance, speed, agility, aerobic or anaerobic capacity, or sports-specific performance related tests. You will receive the results of all tests, which may be used by your coaches to inform your training program. The testing will take place 1 – 4 times per year.
- Biomechanical analysis: Motion capture techniques, are used to analyse athletic movement qualities and sport specific technique. These assessments take place 1 – 4 times per year.
- Complete an annual online medical history questionnaire. You will be provided with a unique user account to an online athlete management system where the form will be completed, and this will take less than 1 hour in total.
- Undergo a standard physical examination, based on recommended procedures for athletes by international bodies such as IOC and FIFA. The examination will be completed annually by a sports physician at the University of Pretoria sports campus.

- Donate a blood sample (15ml or 3 teaspoons). This sample will be used for the extraction and analysis of genetic material (DNA). The DNA will only be used for scientific research purposes relating to determination of the risk of injuries and illness. Samples will be destroyed on completion of the study.
- Complete an illness/injury monitoring questionnaire. Once a week, you will complete a short online questionnaire where you will be asked a few questions about any injuries or illnesses that have occurred. The questionnaire will take no more than 15 minutes to complete.
- Physical load and training response monitoring through a daily questionnaire that will take no more than 5 minutes to complete.
- Complete the Nutritional and Dietary Supplement Assessment monitoring questionnaire once a year
- Provide the research team with access to your academic records.

All questionnaires may be completed on your personal computer, a computer at the university, a tablet, or a smart phone. If using a tablet or smart phone, it can be completed off-line and uploaded when wi-fi connection is available.

Potential risks of this study

- The completion of questionnaires or a physical examination is not associated with any risk. Questionnaires and other clinical data (paper and electronic) will be kept confidential and secure, and will not be made available to any party other than the research team without the consent of the individual participant.
- Musculoskeletal, physiological and biomechanical assessment requires physical tasks that involve some risk of musculoskeletal injury. However, all tasks will involve similar loads and movements that you engage in during regular training and competition. These types of tests are standard procedure in elite sport. You will be allowed to complete a full warm-up routine of your choice before beginning the testing. All reasonable precautions to reduce the risk of injury will be taken, and all testing will be conducted by appropriately qualified staff.
- All medical conditions will be treated as usual by your doctor or physiotherapist, and training will continue as usual under your strength and conditioning trainer.
- The potential risks during the 5 ml (1 teaspoon) blood collection include: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single-use materials.
- Genetic information: To make sure that your specific genetic information is kept secure and confidential, the following procedures will be adopted: 1) all the blood samples will be labelled on collection using a numerical coding system that is linked to player details on a master list that will be placed in a sealed envelope, 2) this sealed master list will then be kept in a secure facility and in a separate location, 3) only the principle investigator and senior co-investigators will have access to this master list, 4) the master list will only be opened if a sample needs to be destroyed, should a participant request this. All data will be analysed anonymously and DNA samples will be destroyed on completion of the study. Your personal genetic information will not be made known to you, your teammates, team medical staff, coaches, or management. The information will be kept secure, anonymous and will only be used for research purposes.

Because this area of research is still in the exploratory phase, we will not be able to provide individual feedback with regards to the results and implications of genetic testing.

- You may withdraw from this study at any time without question.

Potential benefits of this study

You will be provided with the results of your musculoskeletal, physiological and biomechanical assessments, which you may share with your coach or strength and conditioning trainer. The research questions that will be addressed by this study have been identified to have a direct impact on improving health, well-being and performance in student athletes. The anticipated benefits of this study are that the results will further our understanding of the possible cause/s of medical conditions and injuries in athletes.

Ethical Approval

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria (telephone number 012 356 3084) and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

Confidentiality

All records obtained whilst in this study will be regarded as confidential. Once we have analysed the information no one will be able to identify you. Results will be published or presented in such a fashion that participants remain unidentifiable.

Contact

Please feel free to contact a member of the research team or the University of Pretoria Health Sciences Research Office should you have any questions related to the study. You can contact the principal investigator on the following number: (012) 420 1804.

Faculty of Health Sciences - Research Ethics Committee
Tswelopele Building, Level 4, Rooms 4-59 and 4-Faculty of Health Sciences, Dr Savage Road, Gezina, Pretoria
Tel: (012) 356 3084 or (012) 356 3085
Fax: (012) 354 1367
Email: manda.smith@up.ac.za / deepeka.behari@up.ac.za / fhsethics@up.ac.za

University of Pretoria Research Ethics approval number: 83/2016

Consent to participate in this study

I confirm that I have received, read (or had read to me) and understood the above written information regarding the nature, process, risks, discomforts and benefits of the study. I have been given opportunity to submit questions and am satisfied that they have been answered satisfactorily. I agree that research data provided by me or with my permission during the study may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used. I understand that if I do not participate it will not alter my management in any way. I understand that I may withdraw from this study at any time without further question.

I hereby consent to participate in the following components of the study as described in the participant information that I received

Please initial under either "yes" or "no" for each component:

	Yes	No
Functional movement and musculoskeletal screening		
Sport-specific testing		
Biomechanical assessment		
Annual Online Medical History Questionnaire		
Annual Medical Screening Examination		
Weekly illness/injury monitoring questionnaire		
Physical load and daily training response monitoring		
Nutritional and Dietary Supplement Assessment		
Genetic component of this study		
Access to my academic records		

Please complete the participant and witness columns:

	Participant (Athlete)	Witness	Investigator
Name Please Print			To be completed by research team
Signature			To be completed by research team
Date			To be completed by research team

Appendix F: Permission Letter, Research Environment, SEMLI

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

SEMLI
Sport, Exercise Medicine and Lifestyle Institute

26 June 2019

To whom it may concern:

<u>Permission to use SEMLI's facilities and equipment</u>

I hereby grant the following student permission to use SEMLI facilities and equipment for the purposes of his MSc (Sport Science) degree.

- Mr J Swan, student number (10230824)

The title of the project is: "Training load and athlete well-being in university female hockey players during a congested tournament"

____
Prof. M Schwellnus
Director: SEMLI
Faculty of Health Sciences
University of Pretoria

SEMLI, Top Floor, Corner Burnett & Richard Street, Hillcrest Sports Campus, Hatfield, Pretoria

Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

Appendix G: Letter of approval by the Ethics Committee

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

29 August 2019

Approval Certificate
New Application

Ethics Reference No.: 452/2019
Title: Training load and athlete well-being in university female hockey players during a congested tournament

Dear Mr JB Swan

The **New Application** as supported by documents received between 2019-07-04 and 2019-08-28 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-08-28.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-08-29.
- Please remember to use your protocol number (452/2019) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)