Recovery-Stress States and Training Load of Professional Ballet Dancers during a Rehearsal and Performance Phase of a Ballet Year

by

Jana de Wet

Thesis submitted in fulfilment of the requirements for the MSc degree in
Sport Science at Stellenbosch University

Supervisor: Prof RE Venter

Co-supervisor: Dr EK Africa

Department of Sport Science

Faculty of Medicine and Health Sciences

March 2020

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

March 2020

ABSTRACT

Ballet dancers are exposed to high training and performance demands, which make them vulnerable to injury and overtraining. There is, however, a lack of longitudinal studies describing the change in demands placed on ballet dancers during different phases of a ballet season. The aim of the study is to get better insight into the different physical, physiological and psychosocial demands placed on professional ballet dancers during distinct phases of a season.

Professional ballet dancers (male n=10, age: 28 ± 6.0 years, height: 177.9 ± 9.2cm, body mass: 76.2 ± 13.0kg, professional dancing career: 9 ± 6.4 years; female n=17, age: 25 ± 4.2 years, height: 166.2 ± 4.2cm, body mass: 56.5 ± 5.2kg, professional dancing career: 5 ± 4.5 years) from one company in the Western Cape, South Africa, were monitored during two eight-week phases of a ballet season. The Rehearsal Phase (P1) was near the start of the ballet season and the Performance Phase (P2) near the end of the ballet season. Participants were grouped in either a higher-level of performance (soloist and principal dancers [SP]) group or a lower-level of performance (post-graduate and artist [PGA]) group, as well as according to sex (male and female dancers)

During both phases, the Recovery-Stress Questionnaire for Athletes (RESTQ-76 Sport) was utilised once per week to describe dancers' recovery-stress states. Daily, dancers reported their internal training load (TL), making use of the session Rate of Perceived Exertion (RPE) method (sRPE TL), and their pain level using the Self-Estimated Functional Inability because of Pain (SEFIP) questionnaire. External load (impact load) was recorded once per week during P1 with STATSports Vipre® Global Positioning System (GPS) trackers (Ireland). Twenty dancers wore the GPS for the duration of company training and vertical vector magnitude was recorded.

For each variable, a comparison was made between phases (where applicable), sexes and level of performance (SP and PGA). One-way ANOVA was used to compare demographic variables between groups and, a mixed-model ANOVA was used for comparisons of measurements taken over weeks and between phases. Correlation analyses were conducted by means of Pearson and Spearman correlations for TL, recovery-stress state and pain. The level of significance was set to $p \leq 0.05$.

The Performance Phase was signified by lower recovery (TR $p<0.01$), higher stress (TS $p<0.01$) and higher training loads (sRPE TL $p=0.01$) for the total group. Female dancers had significantly lower recovery scores than male dancers during P2 ($p<0.01$). No differentiation in levels were found for any of the variables. No significant difference in pain scores was found between phases or any groups. Significant correlations ($p<0.01$) were found between internal and external training load (Rmcorr=0.25, $p<0.01$), and between training load and pain ($r=0.21$, $p<0.01$). Selected RESTQ-76 Sport stress scales correlated significant positively and recovery scales, negatively, with both pain and training load ($p\leq0.05$).

In conclusion, P2 appeared to be a critical period where dancers were exposed to higher physical and psychological stresses, which increase the risk for injury and the development of overtraining syndrome. It is therefore important to investigate and implement recovery strategies to balance out the high demands during such periods.

Keywords: training load, professional ballet dancer, recovery-stress state, RESTQ-Sport, pain, RPE

ABSTRAK

Ballet dansers word aan hoë oefen- en prestasie eise, wat hulle kwesbaar maak vir beserings en ooroefening, blootgestel. Daar is egter steeds ŉ tekort aan longitudinale studies wat die verandering in eise wat op ballet dansers geplaas word tydens verskillende fases van ŉ ballet seisoen, beskryf. Die doel van die studie is om beter insae te kry in die fisieke, fisiologiese en psigososiale eise van professionele ballet tydens spesifieke fases van ŉ ballet seisoen.

Professionele ballet dansers (mans n=10, ouderdom: 28 ± 6.0 jaar, lengte: 177.9 ± 9.2cm, liggaam massa: 76.2 ± 13.0kg, professionele dansloopbaan: 9 ± 6.4 jare; vroue n=17, ouderdom: 25 ± 4.2 jare, lengte: 166.2 ± 4.2cm, liggaam massa: 56.5 ± 5.2kg, professionele dansloopbaan: 5 ± 4.5 jare) van een dansmaatskappy in die Wes-Kaap, Suid-Afrika, is tydens twee agt-weke fases van ŉ ballet seisoen, gemonitor. Die Repetisie Fase (P1) was nader aan die begin van die ballet seisoen, en die Prestasie Fase (P2) nader aan die einde van die ballet seisoen. Deelnemers was opgedeel in ŉ hoë-vlak prestasie (soliste en hoofdansers [SP]) groep of in ŉ lae-vlak prestasie (nagraads en artist [PGA]) groep, asook volgens geslag (mans en vroue dansers).

Tydens albei fases was die Recovery-Stress Questionnaire for Athletes (RESTQ-76 Sport) een keer per week voltooi om die dansers se herstel-stres toestand te dokumenteer. Dansers het daagliks hul interne oefenlading met gebruik van die sessie Rate of Perceived Exertion (sRPE) metode gerapporteer, asook hulle vlak van pyn met die Self-Estimated Functional Inability because of Pain (SEFIP) vraelys. Eksterne ladingsdata (impak stres) was een keer per week ingesamel tydens P1 met ’n Globale Posisionering Sisteem (GPS; STATSports Vipre ®). Twintig dansers het vir die volle tydperk van die oefening die GPS gedra en vertikale vektor grootte was opgeneem.

Vergelykings tussen fases (waar van toepassing), geslag en vlakke van prestasie (SP en PGA) is vir elke veranderlike getref. Eenrigting ANOVA was gebruik om demografiese veranderlikes tussen groepe te vergelyk en gemengde-model ANOVA was gebruik om vergelykings tussen metings, wat oor weke en tussen fases gemeet is, te tref. Korrelasie analise is met Pearson en Spearman korrelasies bereken vir oefenlading, herstel-stres toestand en pyn. Die vlak van beduidendheid was op $p \leq 0.05$ gestel.

Die Prestasie Fase het laer herstel (TR $p<0.01$), hoër stres (TS $p<0.01$) en hoër oefenlading (sRPE TL $p=0.01$) vir die totale groep aangedui. Vroue dansers het beduidend laer herstel tellings teenoor manlike dansers tydens P2 ($p<0.01$), getoon. Geen verskille was in enige van die veranderlikes tussen die vlakke van prestasie gevind nie. Geen beduidende verskille in pyn tellings tussen fases of enige van die groepe, was gevind nie. Beduidende korrelasies ($p<0.01$) was tussen interne- en eksterne lading gevind (Rmcorr=0.25, $p<0.01$), asook tussen oefenlading en pyn ($r=0.21$, $p<0.01$). Selektiewe RESTQ-76 Sport stres skale het beduidend positief gekorreleer met beide pyn en oefenlading, waar herstel skale beduidend negatiewe korrelasies aangedui het ($p\leq0.05$).

Ter samevatting, blyk die P2 ŉ kritiese periode te wees waar dansers aan hoë fisieke en sielkundige stres blootgestel was, wat die risiko vir beserings verhoog asook die ontwikkeling vir moontlike ooroefening sindroom. Dit is dus belangrik om herstel strategieë te ondersoek en te implementeer om sodoende hoe eise uit te balanseer tydens sulke periodes.

Sleutelwoorde: oefenlading, professionele ballet danser, herstel-stres toestand, RESTQ-Sport, pyn, RPE

ACKNOWLEDGEMENTS

I which to express my deepest appreciation to the following people who all contributed in some way in making this dream of mine to do research on ballet dancers possible:

- Firstly, to my Heavenly Father, You truly make all things work together for my good.
- My supervisor, Prof Ranel Venter and co-supervisor Dr Eileen Africa for all your guidance, support and encouragement throughout the past two years, and for sharing my enthusiasm about this study topic.
- The participating company management for your cooperation during data collection periods. The company dancers for trusting me with your information and taking the time daily to complete the necessary questionnaires.
- The ballet school teacher and dancers for participating in my pilot study.
- Nicole Forest for language and technical editing.
- Prof Kidd, for assisting with data analysis.
- Freda Kemp for assisting with the processing of GPS data.
- Francois Gazzano for sponsoring the use of AthleteMonitoring Software (Canada) in this study.
- Stellenbosch University for providing research travel funds on two occasions, first to accompany the ballet company to Harare, Zimbabwe, giving me the opportunity to work with the dancers backstage on that tour. Second, to present my research at the International Association for Dance Medicine and Science 29th annual conference in Montreal, Canada.
- Dance Trust Zimbabwe for all of your organisational help, and the Griffiths family for taking me into your home and looking after me during my visit to Harare.
- Val Martin, the National Physiotherapy director of education in Zimbabwe, for the organisation around the continuing professional development (CPD) lecture I gave during my visit to Harare.
- My friends for all your support, advice and encouragement. And for sharing my excitement.
- And finally, my parents and family for your never-ending support and encouragement.

DEDICATION

This thesis is dedicated to Aunty Doreen Aitchison who nurtured my initial interest in ballet over the eight years she taught me into a career-driven passion. She is a remarkable woman and role model, and her love for ballet was inspiring.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND TERMINOLOGY

%	Percentage
≥	Greater than or equal to
≤	Smaller than or equal to
*****	Statistically significant difference ($p \leq 0.05$)
******	Statistically significant difference ($p \leq 0.01$)
<	Smaller than
>	Greater than
Cm	Centimetre
BF%	Body fat percentage
G	Gravitational force (G-force)
Kg	Kilogram
M	Meter
N	Number
Yrs	Years
AU	Arbitrary Unit
Ballet season	The 11-month period during which the ballet company trains and performs, starting in April.
Class	Seventy-five-minute technique class at the start of each day. Consisting of barre and centre floor work, with female dancers wearing both ballet flats and pointe shoes at different points during the class.

Dance	In the current study, dance was used as a collective term including ballet, modern dance and/or contemporary dance styles. Where only referring to ballet this was clearly stated.
f/m-SP/PGA	Intra-sex level of performance group
Fatigue	The researcher acknowledges that the concept of fatigue in controversial and can lead to debate, however for the purpose of the current study fatigue refer to an holistic description of perceived fatigue by dancers.
General stress^	A subscale of the main general stress scale and is therefore distinguished with a “^”.
GPS	STATSports Vipre ® Global Positioning System (Technologies Ltd, Version 1.2, Ireland 2012).
Impact load	The functional term used for the accumulation of vertical vector magnitude recorded by GPS trackers for either a full day’s training or per session. Impacts are the number of impacts recorded of at least 3G in magnitude.
Levels of performance	Refer to the SP (higher-level) and PG (lower-level) groups which was determined according to the rank of the dancer in the company.
Off day	Rest day from company activities.
Performance Phase	The second eight-week data collection period near the end of the ballet season, encompassing the most performance intensive period of the company.
PGA	Post-graduates and artists
Rehearsal	Practice of production choreography.
Rehearsal Phase	The first eight-week data collection period near the start of the ballet season, encompassing predominantly classes and rehearsals.

RESTQ	Also RESTQ-76 Sport, Recovery-Stress Questionnaire for Athletes. When referred to simply as RESTQ-Sport, this is either the 76 or the 53 version of the questionnaire.
SEFIP	Self-Estimated Functional Inability because of Pain questionnaire used to collect perceived pain scores daily. A modified version was used, requesting a single holistic pain score.
Session	Refers to either a rehearsal, technique class or performance.
Significant	Statistical significance was set to a power of 95% and a 5% level of significance ($p \leq 0.05$)
SP	Soloists and principal dancers
sRPE	Session Rate of Perceived Exertion. The global RPE score describing the whole session collected after each session.
sRPE TL	Training load calculated with the product of the session’s sRPE score and the duration of the session in minutes.
Team practice	The collective term used to describe both technique classes and rehearsals.
TL	Training load

Chapter One

INTRODUCTION

A. INTRODUCTION

In this chapter, a short overview of the applicable literature will be discussed. The problem statement, purpose and significance together with the potential benefits of the study will follow. Aims and objectives with hypothesis are then stated, followed by the variables and assumptions. Lastly, a brief overview of the chapters will be outlined.

Classical ballet dancers are the focus of the current study. The reader should however note that references to 'dancers' imply ballet, modern and/or contemporary dancers, unless 'ballet dancers' is stated specifically.

B. BACKGROUND

There is a vast variety of dance styles, each with its own identifiable movement patterns, poses, techniques, training methods and key focus areas. All dance styles have their own unique challenges. Ballet dancers are commonly known to endure pain daily (Harrison & Ruddock-Hudson, 2017b) and train for long hours (Fietze et al., 2009; Ramkumar et al., 2016; Da Silva et al., 2015; Wyon, 2010) in a highly competitive and pressurised environment with great focus on physique (Herbrich et al., 2011; Micheli et al., 2005).

Ballet has evolved dramatically since its first documented form as casual artistic entertainment for 16th-century nobility. Uncomplicated choreography was performed by dancers with no formal training who wore heavy, formal gowns and heeled shoes (Lee, 2002). Regardless of the evolution of choreography and consequential changes in the physical demands placed on ballet dancers, ballet still adheres to strict classical principles and standardised positions classified in the late 17th century (Daprati et al., 2009; Sachs, 1937).

Ballet is an intermittent activity (Cohen et al., 1982b; Schantz & Strand, 1984; Twitchett et al., 2009) consisting of slow controlled movements and poses of low to moderate intensity, interceded with periodic high-intensity explosive bursts (Redding & Wyon, 2003; Redding et al., 2004). Many ballet movements and poses are sex-specific, which places different demands on male and female dancers (Wyon et al., 2011). This include the multiple explosive jumps and lift variations of the male dancers' female counterparts which are only required from male ballet dancers and not from female dancers (Wyon et al., 2011). Research has also reported a distinction in the training load of different ranks of dancers within a ballet company (Twitchett et al., 2010). Nevertheless, most research published on ballet dancers regarding cardiovascular demands does not discriminate between male and female dancers in the results.

Ballet classes range from low to moderate aerobic intensity (Cohen, Segal & McArdle, 1982b; Cohen et al., 1982a; Twitchett et al., 2010) and focus predominantly on skill and technique development through repetition. Rehearsals are at low to high aerobic intensity (Guidetti et al., 2007c Rodrigues-Krause et al., 2014; Schantz & Astrand, 1984; Wyon et al., 2004; Wyon & Redding, 2005) and ballet performances have shown to be at moderate to high intensity (Cohen et al., 1982). The discrepancy in the demands imposed by training (including classes and rehearsals), compared to that of a performances has been well reported across different dance styles (Rodrigues-Krause et al., 2015; Wyon, 2005).

A combination of factors in the ballet culture predispose dancers to injury. Inconsistency in injury definition and a reluctance by dancers to report injuries creates difficulty in accurately documenting the injury rate. Ballet dancers often dance through injury and performance pain (Anderson & Hanrahan, 2008; Jacobs et al., 2017; Harrison & Ruddock-Hudson, 2017b). One of the reasons for this is the mindset that pain is an integral part of being a ballet dancer. Another is the competitive environment in which they train (Anderson & Hanrahan, 2008;

Jacobs et al., 2017; Harrison & Ruddock-Hudson, 2017b). Nonetheless, there is consensus among researchers that the injury rate in ballet dancers is high (Jacobs et al., 2017; Ramkumar et al., 2016; Smith et al., 2015), injuries are predominantly overuse in nature (Allen et al., 2012; Twitchett et al., 2010; Ramkumar et al., 2016) and mostly involve the foot or ankle (Nilsson et al., 2001; Ramkumar et al. 2016; Siev-Ner, 2000; Twitchett et al., 2010).

Although injury risk factors in dance are multifold, great emphasis has more recently been placed on the prominent influence of fatigue in injury occurrence (Allen & Wyon, 2008; Liederbach & Compagno, 2001). The positive correlation between injury and fatigue can point to various problematic aspects in the ballet culture and dance training methods. Research has reported dancers to have low cardiovascular capacity compared to other high-performance athletes (Sanders et al., 2019; Wyon et al., 2016). And a low aerobic capacity has been associated with the number and nature of injuries in dancers (Twitchett et al., 2010).

The relatively low aerobic fitness in dancers could be ascribed to the traditional training method still utilised today (Rafferty, 2010; Rodrigues-Krause et al., 2014c). Ballet training predominantly focuses on perfecting and maintaining technique and skill (Rafferty, 2010). Classes and rehearsal have been reported to be insufficient in overall intensity to overload training and consequently improve the aerobic fitness of dancers (Rodrigues-Krause et al., 2014c). As a result, sufficient conditioning for the high physical requirements of present day choreography and extended performance seasons is neglected (Guidetti et al. 2007; Rodrigues-Krause et al., 2014; Schantz & Strand, 1984; Wyon & Redding, 2005).

The timing of evening performances also negatively affects sleep cycles in dancers during performance seasons (Fietze et al., 2009), which could lead to fatigue and cognitive deficits (Banks & Dinges, 2007). Moreover, due to the intensive nature of a ballet season with performances throughout the year and not isolated to one period, companies fail the implementation of training periodisation (Murgia, 2013; Wyon et al., 2004). Training periodisation is recommended for optimal performance as well as to reduce the risk of injury and developing overtraining syndrome (Lorenz et al., 2010). However, little variation can be found in the training schedules of ballet companies throughout the year (Murgia, 2013). Failing to periodise high training loads correctly puts dancers at an increased risk for developing overtraining syndrome (Liederbach & Compagno, 2001).

Another major problematic aspect related to fatigue is the high demand for thinness (Micheli et al., 2005), and the associated chronic calorie restriction and low body fat percentage, especially in female dancers. Calorie restriction has been correlated to injury risk (Liederbach & Compagno, 2001) and low body fat percentage has been correlated to duration of injury rehabilitation (Twitchett et al., 2010a; Twitchett et al., 2008). Liederbach and Compagno (2001) suggested that the risk of overtraining increases when a poor diet is maintained in combination with, or separate of, consistent non-training psychosocial stressors managed by poor coping abilities.

The importance of monitoring athletes for injury management and overtraining risk by means of continuous assessment of training load and psychological profiles has widely been supported (Filho et al., 2015; Grove et al., 2013; Kellmann, 2010). The physical and psychological demands placed on professional ballet dancers have, to date, not been successfully determined and documented. This makes it difficult to develop injury prevention strategies, and to incorporate training and non-training stress management into dancers' routines. Various aspects of the demands placed on dancers by ballet have been investigated independently through cross-sectional studies or over short periods of time such as training load (Surgenor and Wyon, 2019), cardiorespiratory responses, muscle damage and oxidative stress levels during ballet training (Rodrigues-Krause et al., 2014c) and impact force of ballet specific steps (Boros and Skelton, 2009).

It is only recently that psychological assessment in the dance population has garnered more attention (Grove et al., 2013). Blevins et al. (2013) stated that little is known about dancers' management strategies of the stress-recovery balance to maintain and improve performance. Research on the psychological profile of dancers, with reference to recovery-stress states, is limited in published literature. Only five studies on this topic were found, none of which monitored dancers continuously over an extended period of time (Adam et al., 2004; Da Silva et al., 2016; Edmonds et al., 2018; Liederbach & Compagno, 2001).

Training load in dance has been monitored using different subjective and objective methods. Dance studies that utilised the Session Rate of Perceived Exertion method (sRPE) (Foster et al., 2001), accelerometers and heart rate monitors were focused on non-professional ballet dancers, other dance styles or exclusively on female ballet dancers for a single day (Boeding et al., 2019; Da Silva et al., 2015; Jeffries et al., 2017;;Surgenor & Wyon, 2019; Twitchett et al., 2010). Impact load has also been assessed with the use of force plate, and motion and video analysis (Hattie et al., 1997). Only four studies, two using video analysis (Liederbach et al., 2006; Twitchett et al., 2009), and two using the accelerometer (Twitchett et al., 2010; Jeffries et al., 2017), have assessed an entire training day or performance. Adding to this, the last mentioned study was carried out on contemporary dancers. Ground reaction force using the force plate and motion analysis has been investigated for isolated ballet movements (Boros & Skelton, 2009; Chockley, 2008; Kulig et al., 2011; Orishimo et al., 2009; Picon et al., 2008; Walter et al., 2011) or short sequences (Boros & Skelton, 2009).

C. PROBLEM STATEMENT AND MOTIVATION

Literature shows that ballet company culture and training regimes put professional ballet dancers at an increased risk for injury due to fatigue and for developing overtraining syndrome. Despite the growing body of dance science literature, little is known about the psychological and physical demands endured by professional ballet dancers. This includes their recovery-stress profiles during a full ballet season and the differences in demands between rehearsal and performance seasons.

Previous studies have taken glimpses only at the experience of a professional ballet dancer over a full ballet season. To the researcher's knowledge, no longitudinal study has been carried out on the training load and recovery-stress states of professional ballet dancers. This includes monitoring the dancers over different rehearsal and performance phases. With the high number of jumps dancers are expected to perform daily and the dominating percentage of foot and ankle injuries, it is important to assess impact load of long training and performance days. Subjective training load has previously been correlated with different internal and external training load measures, but has not been correlated to impact load (vector magnitude load) in ballet dancers.

The purpose of the study was to gain a better understanding of the psychosocial and physical stressors placed on a professional ballet dancer in the Western Cape, South Africa. The study, firstly, aspired to explore the recovery-stress states, perceived pain and training load (internal and external) of professional ballet dancers during a two-month Rehearsal Phase at the beginning of the ballet season and a two-month Performance Phase at the end of the season. Secondly, it sought to assess differences between phases, sexes and levels of performance in all four of the above-mentioned variables. Finally, the study aimed to assess the associations between recovery-stress states, perceived pain and internal (sRPE) and external (impacts) training load.

The findings of the study could give insight into the way this population manages their recovery-stress states during different phases of preparation and performance during a ballet season. This research should contribute to the body of research on internal training load and impact load this population experiences during rehearsal and performance phases.

D. AIMS, OBJECTIVES, HYPOTHESIS

Research question 1

Does recovery-stress states of professional ballet dancers change over the course of a ballet season?

Aim

To longitudinaly monitor the recovery-stress states of professional ballet dancers over a ballet season. during a Rehearsal (beginning) and Performance (end) Phase of a ballet season.

Objectives

The objectives that guided the data collection for this aim were to determine the weekly recovery-stress states of professional ballet dancers using the RESTQ-76 Sport questionnaire:

To determine differences in recovery-stress states between:

1.1 the Rehearsal Phase and the Performance Phase of the year;

1.2 male and female dancers for the Rehearsal and Performance Phase of the year; and

1.3 the two performance levels (post-graduate and artist [PGA]; soloist and principal [SP]) for the Rehearsal and Performance Phase of the year.

Hypotheses

1.1 The professional ballet dancers will show significantly higher recovery scores and lower stress scores during the Rehearsal Phase compared to the Performance Phase.

1.2 Female dancers will have significantly higher stress scores than male dancers throughout the year.

1.3 Lower-level dancers (PGA) will show significantly more recovery and less stress than higher-level dancers (SP) throughout the year.

Research question 2

Does internal training load of professional ballet dancers change over the course of a ballet season?

Aim

To longitudinally monitor the subjective internal training load of professional ballet dancers over a ballet season.

Objectives

The objectives that guided the data collection for research aim 2 were to determine the training load of professional ballet dancers, using the session-RPE method daily:

To determine differences in subjective internal training load between:

2.1 the Rehearsal Phase and the Performance Phase;

2.2 male and female dancers for the Rehearsal and Performance Phase of a ballet year; and

2.3 the two performance levels (PGA; SP) for the Rehearsal and Performance Phases of the year.

Hypotheses

2.1 The subjective training load would be significantly higher during the Performance Phase compared to the Rehearsal Phase.

2.2 There will be no significant difference in subjective training load between male and female dancers throughout the year.

2.3 Higher-level dancers would have significantly higher perceived training load compared to lower-level dancers.

Research question 3

What is the external training load of professional ballet dancers during a rehearsal phase?

Aim

To longitudinally monitor external training load of professional ballet dancers over a rehearsal phase.

Objectives

The objectives that guided the data collection for research aim 3 were to determine the external training load as impacts of professional ballet dancers, using a Global Positioning Systems (GPS) weekly:

To determine differences in impacts (GPS) during the Rehearsal Phase between:

3.1 consecutive weeks during the Rehearsal Phase;

3.2 male and female dancers; and

3.3 the higher- and lower-level dancers.

Hypotheses

3.1 There will be no significant inter-week differences in impacts during the Rehearsal Phase.

3.2 There will be no significant difference between male and female dancers in terms of impacts.

3.3 Higher-level dancers would experience significantly more impacts than lower-level dancers.

Research question 4

Does perceived pain of professional ballet dancers change over the course of a ballet season?

Aim

To longitudinally monitor perceived pain of professional ballet dancers over a ballet season.

Objectives

The objectives that guided the data collection for research aim 4 were to determine the perceived pain of professional ballet dancers, using the Self Estimated Functional Inability Because Of Pain questionnaire daily:

To determine differences in perceived pain between:

4.1 the Rehearsal Phase and the Performance Phase of the season;

4.2 male and female dancers for the Rehearsal and Performance Phase of the season; and

4.3 the two levels of performance (PGA; SP) for the Rehearsal and Performance Phase of the season.

Hypotheses

4.1 Perceived pain would be significantly higher during Performance Phase compared to Rehearsal Phase.

4.2 There will be no significant difference in perceived pain between male and female dancers.

4.3 Perceived pain would be significantly more in higher-level dancers compared to lower-level dancers during both phases.

Research question 5

Is there an association between recovery-stress states, training load and perceived pain of professional ballet dancers over the course of a ballet season?

Aim

To determine the relationship between perceived pain, internal and external training load, and recovery-stress states of professional ballet dancers during a Rehearsal and, in some of cases, a Performance Phase of a ballet season.

Objectives

5.1 To determine the relationship between the four main recovery-stress scales (general stress, general recovery, sport-specific stress, sport-specific recovery) and the preceding week's internal training load during the Rehearsal and Performance Phases of the season for:

- 5.1.1 the total group of dancers;
- 5.1.2 male and female dancers; and
- 5.1.3 the two performance levels.

Hypotheses

5.1 Subjective training load would have a significant positive correlation with stress scores and a significant negative correlation with recovery scores for all groups during both phases.

Objective

5.2 To determine the relationship between the four main recovery-stress scales (general stress, general recovery, sport-specific stress, sport-specific recovery) and the subsequent week's perceived pain during the Rehearsal and the Performance Phases of the season for:

- 5.2.1 the total group of dancers;
- 5.2.2 male and female dancers; and

5.2.3 the two performance levels.

Hypotheses

5.2 Pain scores would have a significant positive correlation with stress scores and a significant negative correlation with recovery scores for all groups during both phases.

Objective

5.3 To determine the relationship between perceived pain and the day's accumulated internal training load of all dance and non-dance physical activities in professional ballet dancers during a season for:

5.3.1 the total group of dancers;
5.3.2 male and female dancers; and
5.3.3 the two levels of performance.

Hypotheses

5.3 Pain would positively correlate with subjective training load for all groups.

Objective

5.4 To determine the relationship between internal training load (sRPE) and external training load (impacts measured by GPS) of professional ballet dancers during a Rehearsal Phase.

Hypotheses

5.4 Internal training load (impacts) would have a significant positive correlation with external training load in dancers.

H. VARIABLES

Independent variables

- Company training and performance schedules

Dependent variables

- Recovery-stress states
- Perceived pain
- External training load (GPS variables)
- Internal training load (sRPE)

Categorical variables

- Sex
- Level of performance
- Phases of season

I. ASSUMPTIONS

It was assumed that:

1. all dancers have answered all questions on the continuous reporting of their recovery-stress questionnaire, as well as pain occurrence, sRPE of daily training and total athletic hours, honestly and accurately;
2. all dancers have exerted optimal effort during rehearsals and performances; and
3. subjective and objective instruments used for data collection during the study elicited valid and reliable responses

J. OUTLINE OF THESIS

Chapter Two contains the theoretical background for the current study by reviewing relevant literature on the evolution of ballet, physical and psychological demands placed on ballet dancers and associated challenges of professional ballet dancers. Furthermore, an overview of monitoring methods and literature on recovery and training load will be given. In Chapter Three, the detailed methods of data collection are explained, while Chapter Four contains the results of the current study. Finally, in Chapter Five a discussion of the aims and objectives together with the main findings is done. This chapter will also include the overall conclusion to the study, limitations of the study and recommendations for future research.

The referencing style used in the current study is the “Harvard-Stellenbosch University” method.

Chapter Two

THEORETICAL CONTEXT

A. INTRODUCTION

In this chapter an overview of the theoretical context will be give firstly on ballet specifically, including the historic perspective thereof and the current training and performance demands of ballet dancers. Injuries and associated physical challenges on ballet dancers will be discussed, including the pain-enduring culture and the role fatigue plays in dance injuries. The following two sections will discuss monitoring methods with the focus on fatigue management through recovery and training load monitoring.

B. BALLET

The historical evolution of ballet is evident of the elevated demands placed on ballet dancers today compared to the first documented ballet production. The next section includes a short overview of main turns in history in the development of ballet to how we know it today. Current training and performance demands on ballet dancers will follow with reference to how this has increased since the early form of classical ballet.

Historical perspective

The modern-day ballet dancer is described as "both artist and athlete, performing complex artistic routines that require a high level of athletic ability due to the extreme physical demands placed on them" (Allen et al., 2012: 781). This description of ballet dancers is far removed from the ballet dancers of the 16th century, who performed as casual entertainers (Lee, 2002).

The first documented ballet production, Ballet de Polonaise, was performed in Paris in 1573 (Lee, 2002: 43). Before that even, ballet in its earlies form, were used as a form of entertainment at extravagant events for nobility. The court performed relative simple and uncomplicated choreography in heeled shoes and formal, heavy gowns (Lee, 2002: 42). The first ballet academy, Académie Royale de Danse, was opened in 1661 in Paris with formal ballet training (Lee, 2002: 69), after which ballet more closely began to resemble the dance as it is known today. Around 1680, Pierre Beauchamp classified and recorded the five basic positions for the feet and arms that are still used today (Sachs, 1937).

In the mid-18th century to the first half of the 19th century, ballet dancers' costumes changed drastically. Ballet dancers traded their heeled shoes for flat, soft-soled satin shoes and the costumes of dancers evolved from heavy, formal gowns to light calf-length skirts known as the romantic tutu (Pittsburg Ballet Theatre, n.d). Pointe shoes were later introduced, making possible for dancers to balance longer on the tips of their toes during performance (Lee, 2002).

In the second half of the 19th century, Russian choreographers increased the demands and difficulty of ballet by increasing the precision of movements and incorporating complicated sequences with pointe work, leaps and turns. They also advanced extension and turn-out of the legs (Pittsburg Ballet Theatre, n.d). Russian choreographers further developed ballet in the early 20th century, moving beyond the classical form and introducing neoclassical ballet and contemporary 'plotless' ballet. Contemporary ballet is strongly influenced by both classical ballet and modern dance. It emphasises the expression of music through movement and highlights human emotion without conveying a definite storyline (Pittsburg Ballet Theatre, n.d). The entire body is used to create free movements and encompasses greater ranges of movement. The classical technique, however, remains the cornerstone of these styles and female dancers still perform with pointe shoes.

While modern-day stage performances are often repetitions of popular classics choreographed in the 20th century (Daprati et al., 2009), progression in body posture alignment of specific ballet poses has become evident. The amount of leg elevation in certain ballet poses, for example, has significantly increased during the period from 1946 to 2004

(Daprati et al., 2009). After analysing visual images of six standard ballet body poses, retrieved from the archives of the Royal Opera House, Daprati et al. (2009) indicated that the angles of leg elevation have significantly increased over the years. These changes could be ascribed either to improved physical fitness of dancers or to aesthetic preference of different time periods (Daprati et al., 2009).

A summary of the major events and changes impacting the evolvement of classical ballet is shown in Table 2.1. The content of the table was primarily based on Lee (2002), Pittsburg Ballet Theatre (n.d.) and Sachs (1937).

Table 2.1 **Classical ballet: Changes in clothing and physical demands over time**

	Shoes	Costume	Physical demands / skill requirements
16th century	- Heeled shoes	- Female: heavy, formal gowns	- Relatively simple and uncomplicated choreography to music - First documented ballet production (1573)
17th century		- Female: heavy, formal gowns - Male: wired skirts of brocade or similar material - Leather masks (comic or tragic)	- Formal ballet training introduced - Five foundational positions codified - Ballet elements incorporated into opera performances (moved from courts to stage)
18th century	- Heeled shoes changed for soft satin shoes (ballet flats)	- Romantic tutu (calf-length light skirt made of tulle)	- Became art form in its own right - Introduced grand jete, pirouette and fully extend their feet (point their toes)
19th century	- Reinforcing toe of ballet flats - Reinforced midsole - Pointe shoes introduced	Shorter classical tutu	- Introduction to pointe work - Russian choreographers' influence increases demands on dancers (leg extension, turn-out, pointe work, complicated sequences, leaps, turns, precision of movement)

20th century	- Synthetic material incorporated into shoes (shock absorption foams and plastic)	- Neo-classical ballet - Contemporary ‘plotless’ ballet - More free movements (whole body movements), floor work, contact between dancers, falls and weight transfer from hands to feet

Training and performance demands

Although classical ballet continues to adhere to strict principles and standardised positions (Daprati et al., 2009), the anatomic and physical demands have increased with modern choreography (McLain, 1983) and performance schedules (Koutedakis & Jamurtas, 2004). This requires the development of dancers' physical and physiological fitness to be as important as skill development (Koutedakis & Jamurtas, 2004).

Ballet is regarded as intermittent exercise (Cohen et al., 1982b; Schantz & Strand, 1984; Twitchett et al., 2009), consisting of brief sets of high intensity bursts (allegro) and longer sets of slow movements and static poses emphasising balance and control (adagio) (Guidetti et al., 2007). Movement control is predominantly facilitated by the use of eccentric and isometric muscle contractions (Rodrigues-Krause, et al., 2014c).

Traditional ballet training, primarily focusing on technique and skill development and maintenance, is no longer sufficient for the increased demands of modern choreography (Guidetti et al., 2007; Rodrigues-Krause et al., 2014; Schantz & Strand, 1984; Wyon & Redding, 2005). Twitchett et al. (2009) suggest that physiological capacity might be the limiting factor for dancers to meet their performance capabilities, as opposed to artistic limitations. Multiple researchers have recommended the supplementation of dance training with additional fitness sessions in order to bridge the gap between training and performance demands (Sanders et al., 2019; Twitchett, Koutedakis, et al., 2009; Wyon, 2012).

As described above, ballet classes, rehearsals and performances place different demands on the dancer (Rodrigues-Krause , et al., 2014c; Wyon & Redding, 2005). Typical classes range from low to moderate aerobic intensity, with a higher overload of eccentric muscle contraction due to numerous repetitions for technique development (Rodrigues-Krause et al., 2014c). A typical class can be divided into three main sections. These sections are distinguished from one another due to the type of movements practiced in each, which consequently also make each section unique in terms of physical and physiological demands. Table 2.1 gives an overview of the class structure and training intensities.

Table 2.2 Typical ballet class structure and training intensity

		Class section	Intervals	Exercise intensity	Energy system
Class		**Barre**	60 seconds of exercise; 30 seconds of rest	Low to moderate intensity	Aerobic oxidative pathways
	Centre floor	**Part 1 (Adagio)**	35 seconds of exercise; 85 seconds of rest	Moderate intensity	Aerobic oxidative pathways
		Part 2 (Allegro) leaps, explosive and repetitive jumps	15 seconds of exercise; 75 seconds of rest	Higher aerobic intensity	Anaerobic-alactic system, anaerobic-lactic system

Note: (Cohen, Segal & McArdle, 1982b; Cohen et al., 1982a; Guidetti et al., 2007c; Koutedakis & Jamurtas, 2004; Rodrigues-Krause et al., 2014; Schantz & Strand, 1984; Twitchett et al., 2010)

Rehearsals include anaerobic (Rodrigues-Krause et al., 2014c) as well as low to high aerobic intensity (Rodrigues-Krause et al., 2014; Schantz & Astrand, 1984; Wyon et al., 2004; Wyon & Redding, 2005), with more focus on technical-artistic combinations (Rodrigues-Krause et al., 2014c). Performances have been reported to be similar to centre practice exercises, with an average heart rate (HR) between 70% and 95% of age-predicted maximum HR (HRmax) and a maximum HR between 79% and 100% of HRmax (Cohen et al., 1982b).

The energy systems used depend on a variety of different aspects. A ballet dancer’s sex and rank plays a role in the dance demands they will experience (Twitchett et al., 2010). Female dancers at different ranks within a ballet company have shown to train at significantly different intensities and spend different amounts of time at specific intensities during class and rehearsal (Twitchett et al., 2010). Male and female ballet dancers perform sex-specific skills (Wyon et al., 2011) that place different demands on their bodies. In addition to a dancers sex, rank in a company and whether they are busy with class, rehearsal or performance, the dance style and choreography also contribute to the energy systems used at the particular moment (Allen et al., 2012; Wyon et al., 2011). Even though all energy systems are used all the time, the percentage of each system used are different. The anaerobic-alactic system and anaerobic-lactic system are used during allegro sets when leaps, explosive and repetitive jumps are performed. These sections require muscle power reserves and muscular endurance. The aerobic oxidative pathways are used during low-intensity exercises that require cardiorespiratory endurance, such as grand adagio (Koutedakis & Jamurtas, 2004). These physiological demands are similar to that of soccer and tennis in that moments of high intensity surges are interchanged with moments where precision and skill are required (Twitchett et al., 2009). Although rhythmic and artistic gymnastics and ballet share the requirement for expressiveness and high levels of flexibility (Twitchett et al., 2009), it has been indicated that the physical intensity of ballet is lower due to longer work bouts (four minutes) compared to rhythmic gymnastics routines (60–90 seconds) (Baldari & Guidetti, 2001).

Other physical demands placed on ballet dancers are extreme flexibility and joint range of motion and low body fat percentage for aesthetic reasons (Koutedakis & Jamurtas, 2004; Koutedakis et al., 1999).

This section gave an overview of the physical and physiological demands placed on ballet dancers and should provide background for the following section on injuries in ballet dancers.

C. INJURIES AND ACCOCIATED CHALLENGES ON BALLET DANCERS

Injury and the risk of being injured is a constant concern in all sports. Literature has highlighted that dancers are at an especially high risk for injury due to dance-specific factors. Some dance-specific factors relating to injury risk include the dancing environment (floors and room temperature), pointe shoes, extreme flexibility and range of motion, the nature of repetitive training, lack of effective training periodisation, long daily training hours, the combination of highly technical skills and physiological demands, and the 'show must go on' mentality that causes dancers to work (dance) through pain (Harrison & Ruddock-Hudson, 2017). Injuries, the pain-enduring culture and the role fatigue plays in injury occurrence will be discussed in the following sections. It should be noted that in some instances a large variety of information on participants are reported in the original article but not all of it will be given in the following discussion.

Injuries

There is agreement among researchers that the majority of ballet injuries are overuse injuries (Allen et al., 2012; Nilsson et al., 2001; Ramkumar et al., 2016; Siev-Ner, 2000; Sobrino and Guillén, 2017a; Twitchett et al., 2010). Laws et al., (2005) reported that more than half of the injuries in professional ballet dancers are to muscles and second most injuries involve joints. The rate of prevalence was further in the order of tendon-related injuries, bone-related injuries and only 5% as other types of injuries. In ballet, the foot and the ankle are the areas most often injured (Nilsson et al., 2001; Ramkumar et al. 2016; Siev-Ner, 2000; Twitchett et al., 2010).

Differences in injury rate between ranks in a professional ballet company as well as between sexes has also been shown (Allen et al., 2012; Harrison & Ruddock-Hudson, 2017a; Jacobs et al., 2017). In Allen et al., (2012) they reported artists had the most injuries overall and male artists more than female artists. The authors ascribed it to the roles the different sexes dance and to the increase in work load the younger dancers experience when new to the company. On contrast to Allen et al. (2012), Harrison & Ruddock-Hudson (2017a) and Jacobs et al. (2017) reported higher injury rate in more experienced and higher ranked dancers. Differences in results might be due to the population the last two mentioned studies included, they included ballet as well as other dance styles from more than one company as well as retired dancers, while the first study only included one ballet company.

The largest study documenting injuries in professional ballet dancers was carried out by Ramkumar et al. (2016). The retrospective study was performed on one of America's largest ballet companies for the period from 2000 to 2010. It included the injury records of 153 dancers (average age: 27.5 years; sex: 53% female, 47% male; dance rehearsal time per week: 27.5 hours), which were collected from the company's designated 'team physicians', in-house athletic trainers and physical therapists. The average number of dancers in the company per year was 52. Injury was defined as "anatomic tissue-level impairment as diagnosed by a health care practitioner that resulted in full time loss from activity for one more day beyond the day of onset, in accordance with SMCI guidelines" (Ramkumar et al., 2016:31). Injuries were documented according to the anatomical location and the diagnosis. The location most injured was the ankle and foot collectively (220 injuries, 38%), followed by the lumbar spine (117 injuries, 20%) and cervical spine (55 injuries, 10%). The most prevalent diagnosis was lumbar strain, accounting for 20% of all injuries. The most common acute injury was ankle sprains (10%), a finding that was consistent with previous studies. Injury incidence rate per annum was 1.10. The injury incidence rate per 1 000 hours of training was 0.91. One of the study's limitations was the inability to differentiate between acute and overuse injuries (except for those where the name states the nature of the injury).

Allen et al. (2012) used a time-loss injury definition to assess the number and severity of injury incidences in a ballet company over one year. Fifty-two dancers participated in the study (male: 25; female: 27). The injured dancer had to be booked off from participating in all company activities for 24 hours or more for the incident to be recorded as an injury. Injury incidence per 1 000 hours was 4.4 injuries (male 4.8; female, 4.1; $P>.05$) and the average injuries per dancer were 6.8 injuries (male, 7.3; female, 6.3; $P>.05$). Severity of injuries was significantly higher in males (nine days off) compared to females (four days off). The majority of injuries for both male (60%) and female (64%) dancers were overuse injuries ($p>0.05$).

Although the injury rate per year (1.1 injuries per dancer) (Ramkumar et al., 2016) does not appear to be high in comparison to other high-performance sports, dancers are not able to return to the stage immediately after the injury has been rehabilitated, as with most traditional sports (Allen & Wyon, 2008). Ballet dancers train together for hours every day to learn choreography involving a complex variety of movement patterns, perfect technique, and to dance synchronously or asynchronously with other dancers. These factors add to the disruption of dance injuries and to the effect they have on participation in a production. (Allen & Wyon, 2008).

Askling et al. (2006) provided another explanation for the difference in time to return to pre-injury performance level between dancers and sport codes. They reported that student and professional dancers (ballet and modern) took on average 50 weeks (range: 30–76 weeks) to return to pre-injury performance level after a first-time hamstring strain. In the same study, elite sprinters, took on average only 16 weeks (range: 6–50 weeks). The study included 15 modern and classical ballet dancers (level: student and professional; age: 16–24 years; sex: 14 female, 1 male), and 18 elite sprinters (level: national and international level; age: 15–28 years; sex: 8 female, 10 male). Hip flexion range of motion and knee flexion isometric strength were measured at 10, 21 and 42 days after injury. Even though both sprinters and dancers could perform more than 90% of uninjured leg's test values at 42 days post injury, actual time to return to pre-injured performance level took much longer in dancers. These results support the suggestion that injuries sustained by dancers may influence their professional careers to a greater extent compared to many traditional sports.

Injury rate is also influenced by a dance company's financial status and has been found to play an integral part in the health of company dancers. Some companies are fortunate enough to have in-house health professionals who take care of the dancers' needs. However, in many companies this is not possible. As mentioned before, a low company income was reported to be a main factor associated with pain scores ≥3 (SEFIP questionnaire) in modern dancers (Jacobs et al, 2017). It is common for dance companies to have very limited funding and most companies are non-profitable organisations. A group of professional dancers said there is a lack of support and funding in the dance industry in Australia (Harrison & Ruddock-Hudson, 2017b). The Cape Town City Ballet and the Joburg Ballet companies in South Africa are both dependent on donations from the public and income from productions they put on (Bosch, 2019; van Wyk, 2019). Jacobs et al. (2017) emphasised the importance of further investigation of societal and company differences among countries. Documenting the injury rate of ballet dancers can be challenging due to ballet companies and the ballet culture that typically foster a pain-enduring culture.

The pain-enduring culture

Studies investigating injuries in the dance population often use self-reported injury forms or injury records from either the company's medical division or a secondary source such as a health institution that works in collaboration with the dance company.

A systematic review by Hincapié et al. (2008) stated that there has been a lack of consistency in definition for injury in the dance population. In 2012, the International Association of Dance Medicine and Science gave recommendations regarding injury definition (Liederbach et al., 2012). It recommended the inclusion of an anatomic tissue-level diagnosis made by a healthcare practitioner in the definition, which resulted in complete time-loss from activity for at least 24 hours. The challenge with this injury definition, however, is that dancers often dance through pain, withhold reporting of minor injuries (Harrison & Ruddock-Hudson, 2017b) and do not always take time off from work. Therefore, this definition might underestimate injury rate (Bronner et al., 2006). Bronner et al. (2006) recommended the following injury definition to be used "injury is any physical compliant sustained by a dancer resulting from company performance, rehearsal, or technique class, irrespective of the need for medical attention or time-loss from activities".

Withholding reporting of minor injuries can lead to the development of severe and sometimes career-ending injuries (Harrison & Ruddock-Hudson, 2017). Jacobs et al., (2017) documented the reasons for not reporting injuries in dancers. The study included 260 professional dancers from three ballet and six contemporary companies (style: 178 ballet [female, 104; male, 74]; 82 modern dance [female, 41; male, 41]; average age: 21–30 years). Two methods were used to report dance-related musculoskeletal (MSK) injury. Each method represented a specific injury definition. a) Self-Estimated Functional Inability because of pain (SEFIP) questionnaire, an answer of ≥3 was documented as an injury. It should be noted that a dancer could have significant pain in multiple body areas and still not have a score ≥3. b) Self–reported injury indicated a current injury.

Dancers with self-reported injury who did not report the injury to any company or independent health professional had to indicate the reason for this. Results showed that injuries were more likely to be reported by soloist and principal dancers than by corps de ballet dancers (artists). Although not statistically significant, male dancers were more likely to report injuries (60.8%) compared to female dancers (52.5%). In ballet dancers, SEFIP scores ≥3 were only associated with the years dancing professionally (OR = 4.4, 95% CI, 1.6 – 12.3). Dancers who had danced professionally ≤3 years were less likely to have a pain score of ≥ 3, compared to dancers who have danced 9–15.4 years professional experience. For modern dancers, a low income was one of the factors associated with pain scores ≥3.

More than 15% of dancers (modern and ballet) did not report their injuries. Reasons for not reporting an injury are listed in Table 2.3 below. The most common reasons stated were that the dancer felt that they could cope with the pain, it did not affect their work and that pain is an inherent part of dancing. Jacobs et al., (2017) stated all dancers should have the freedom to report injuries and take the appropriate prescribed time off (necessary for full recovery) without having the fear of losing their jobs.

Table 2.3 **Reasons for not reporting an injury in ballet and modern professional dancers (Jacobs et al., 2017:158).**

Reason for not reporting an injury	N = 15 n (%)
I can cope with the pain	8 (53.3)
It did not affect my work	6 (40.0)
Pain is an inherent part of dancing	5 (33.3)
I did not want to stop dancing	4 (26.7)
I did not feel it was important	3 (20.0)
I did not want to be seen as unreliable	3 (20.0)
I did not want to negatively affect the production	3 (20.0)
I did not want to lose a role	2 (13.3)
I did not want to let my company down	2 (13.3)
Other	1 (7.1)

Harrison and Ruddock-Hudson (2017b) also supported the notion that “aches and pains are an integral part of the life of a dancer”. The authors conducted a pilot study using semi-structured interviews and the SEFIP questionnaire. Twenty professional and former professional dancers (country: Canada, United Kingdom, Australia; age: 25–45; sex: 11 female, 9 male; position: 14 retired on average 5.6 years before study). The study included various dance styles, but the majority of dancers had experience in ballet and contemporary dance. Results indicated that dancers understood performance pain as “good pain” associated with fitness gains and short-term “pleasurable discomfort” and injury pain as “bad pain” associated with “uncomfortable”, “sharp” and “nerve pains”. Almost all the dancers reported that pain was to be expected in their daily lives as dancers, and should be managed, rather than avoided, and pushed through. It was also stated that there is a perception about pain being an indicator of benefits. Dancers psychologically block the pain during training and performance to continue dancing, some even passed the point of recovery. Only a few said they hold back in class and during rehearsal as a management strategy and only one said they never dance through pain. Eleven of the dancers reported that their bodies felt “over-sensitized” at a later stage in their dancing careers due to their high pain threshold in their younger years. They could no longer push through the same high pain levels as before.

Anderson and Hanrahan (2008) reported contrasting findings to Harrison and Ruddock-Hudson (2017). Anderson and Hanrahan (2008) stated that dancers could not necessarily differentiate between performance and injury pain. They also reported that dancers did not differ in the coping strategies they applied to different types of pain perceived. Nevertheless, dancers who experienced performance pain were more likely to dance through the pain than when injury pain was experienced. Anderson and Hanrahan (2008) included only professional ballet and contemporary dancers (N: 51; mean age: 25.9 years). In this study dancers completed four pain questionnaires that investigated their attitudes towards performance pain and injury pain: a general pain questionnaire, the Pain Appraisal Inventory, the Survey of Pain Attitudes Control Subscale, and the Sports Inventory for Pain.

Differences in findings may be attributed to the small sample size and, more importantly, the population sample used by Harrison and Ruddock-Hudson (2017). According to the authors, the memory of pain experienced by and pain appraisal for years of activity of retired dancers from different dance styles, might have been influenced by the amount of time that had elapsed between retirement and the survey.

Multiple factors contribute to injury occurrence in sport. In dancers specifically, emphasis has recently been placed on the prominent role the fatigue plays in injury occurrence.

The role of fatigue in injuries

Fatigue is multidimensional and in the current study reference will be made to the holistic concept of fatigue. In the dance population, fatigue has been documented in various ways, including injury from self-report, Profile of Mood States (POMS) questionnaire scores, exposure hours on day of injury occurrence and time of injury. A strong correlation has been found between fatigue and the time of injury occurrence (Liederbach & Compagno, 2001). Aspects in the ballet population contributing to fatigue, such as aerobic fitness and its association with training challenges, sleep and calorie restriction, will be reviewed.

Allen and Wyon (2008) stated that due to the high skilled level of dance, even mild fatigue will place dancers at increased risk for injury due to the effect fatigue have on dancer's technique and consequently bodily alignment affecting the force misplacement.

In a longitudinal study of ballet dancers conducted over two years, Liederbach and Compagno (2001) found a strong association between injury and various measures of fatigue and consequently support the concern regarding the association between fatigue and injury. The study included 500 dance injury reports submitted by a total of 644 dancers (university dancers and professional ballet dancers). On-site physical therapists at three different sites collected injury reports (university conservatory, an urban orthopaedic clinic that specialised in the evaluation and treatment of dance injuries, and a professional ballet company). Of the study group, 90% of dancers reported that they felt tired at the time when injury occurred. Additionally, the injured cohort scored higher on the Profile of Mood States (POMS) questionnaire's fatigue item at the start of the study, compared to the non-injured dancers. The study indicated that 79% of all injuries occurred in the evening (all but two injuries after ≥ 5h of dance activity), 67% injuries occurred between the middle and the end of a performance season or semester, 79% dancers were engaged in familiar repertory work, 80% were injured during self-described high-intensity dance (HR>160bpm) and 69% of dancers were dieting to lose weight at the time of injury.

Various reasons for fatigue in dancers have been suggested. Aerobic capacity has been reported to have a strong correlation to the number and type of injury in ballet dancers (Twitchett et al., 2010a). Multiple studies has reported dancers, including ballet dancers, have lower aerobic and anaerobic capacities compared to other high-performance athletes on an professional as well as college level (Rodrigues-Krause et al., 2015a; Sanders et al., 2019).

Twitchett et al. (2010a) concluded the association between aerobic fitness and injury rate with the completion of their study where a sample of 13 elite female ballet dancers (Age: 19 ± 0.7 years) was monitored over a 15-week period. Aerobic capacity was determined with the 20-minute multistage dance-specific aerobic fitness test (DAFT). Injuries were recorded by a healthcare professional who treated the dancers for the 15 weeks following assessments. Heart rate recorded at the end of the DAFT test was positively correlated to the number of injuries sustained over the 15-week period (r=0.590, p=0.034) and non-statistically significant related to acute injuries specifically.

Chmelar et al. (1988) also concluded that there is a difference in physiological profiles of female dancers depending on their performance level and dance style. The authors showed that professional ballet dancers have significantly lower aerobic and anaerobic capacity compared to university-level ballet dancers, contemporary professional and -student dancers. Chemelar et al. (1988) used both a Treadmill and Wingate test in their study. The lower aerobic capacity reported by this study might be explained by the movement efficiency of professional ballet dancers while performing ballet steps, which causes ballet dancers' anaerobic systems not to be challenged while dancing (Twitchett et al., 2009).

An explanation as to why dancers might have a higher risk for injury compare to athletes when taking their aerobic capacity into account was offered by Twitchett et al. (2009). The authors suggest that although dancers' energy efficiency slightly offsets the lack in aerobic capacity, technique is still compromised once fatigue sets in during dancing. Accumulation of blood lactate causes a decrease in coordination, balance and composure (Baldari & Guidetti, 2001; Twitchett et al., 2009). With landing and lifting alignment affected, the body is exposed to dangerous sheer and rotational forces that increase the risk for injury (Twitchett et al., 2009). While sportspeople have a good physical fitness foundation to fall back on when technique fails, classical ballet dancers lack that reserve (Allen &Wyon, 2008) and are thus at higher risk for injury when fatigued.

The deficiency of cardiovascular capacity in ballet dancers, despite the long daily training hours of professional ballet dancers could likely be due to various shortcomings related to the traditional training methods still utilized by ballet companies currently. First, ballet classes focus predominantly on technique improvement (Rodrigues-Krause et al., 2014c) and not on the advancement of cardiovascular capacity. Second, dancers only actively take part during classes for about 50% of the class time collectively (Guidetti et al., 2007c). The findings of Guidetti et al. (2007c) agreed with those of Schantz and Strand (1984). Schantz and Strand (1984) reported professional classical ballet dancers were actively engaged in exercise for only 50 minutes of a 75 minute ballet class. According to multiple studies repotted in Rodrigues-Krause et al. (2015a)'s review article, 50% active dance time is not enough to strain and improve the cardiorespiratory system of dancers. The third reason for the deficiency in cardiovascular capacity could be that the intensity of classes and rehearsals are at too low intensity to improve the cardiorespiratory capacity, partially due to the frequent rest periods during classes. Finally, the principle of progressive overloading is not followed in ballet, as there is little variation in training schedules (training periodisation) in ballet companies year round (Murgia, 2013). These traditional methods do not provide the training stimulus for the cardiorespiratory adaptations needed for a full performance season. Training intensity only increases shortly before a performance once the production has been learned and put together (Wyon et al., 2004). Wyon et al. (2004) state that an increase in intensity shortly before the show is too late for improvement in the cardiorespiratory system to take place.

Rodrigues-Krause et al. (2014c) reported on the cardiorespiratory and oxidative demands of classical ballet class and a rehearsal of advanced dancers. According to oxygen uptake and heart rate (HR), exercise demands for the class stayed close to the first ventilator threshold (VT1) and for the rehearsal between VT1 and the second ventilator threshold (VT2). While oxygen uptake (VO_2) indicated very low-aerobic workloads during class and reported rehearsal intensity also falling below VT1, HR showed slightly higher values. HR indicated rehearsal intensity was between VT1 and VT2. Nevertheless, the authors concluded that it is unlikely that training stimulus is enough to provide cardiorespiratory adaptations needed for a full performance season.

The veracity of this statement by Rodrigues-Krause et al. (2014c) in relation to contemporary dancers was supported by Wyon and Redding (2005). Wyon & Redding (2005) reported that dancers' aerobic capacity improved over the performance season, but not over the rehearsal phase. The conclusion was that class and rehearsal training alone are insufficient in preparing dancers physiologically for performance season. In their study, the authors tested 17 professional contemporary dancers from two companies (8 male, 9 female; average age: 22–23 years). Data collection started one to two weeks after a company break (two to three weeks prior the start of rehearsal period). Each dancer's baseline aerobic fitness was determined with a multistage dance aerobic fitness test. Heart rate and blood lactate measurements were taken in the last phase of the test and one minute after test termination. The test was repeated one week before the start of performance period (week 12) and finally again one week after the performance period (week 20). Results indicated an improvement in aerobic capacity after performance period, but not after rehearsal period. The results confirmed that dance training load is not enough to improve the dancers' aerobic capacity during the preparation period. This study also demonstrates that there is a discrepancy in the physiological demands placed on dancers during training sessions opposed to during performances.

Furthermore, demanding performance schedules negatively affect dancers sleep cycles (Fietze et al., 2009) consequently leading to daytime sleepiness and affecting cognitive deficits (Banks & Dinges, 2007). Fietze et al. (2009) stated that the two main potential risks for dancers are physical injury and altered sleep. The authors monitored professional ballet dancers' sleep quality over a 67-day period prior to a premier. The study was carried out on 24 professional ballet dancers (age: 18–40 years; sex: 15 female [age starting dance career: 6.57 ± 2.47 years], 9 male [age starting dance career: 7.33 ± 2.10 years]).

Participants were asked to complete the following questionnaires once at the beginning of the monitoring period: Epworth Sleepiness Scale, for assessment of sleepiness; Pittsburgh Sleep Quality Index, for sleep habits; Quality of Life Questionnaire, for general wellbeing in its SF-12 short form for health status for general wellbeing; d2 Test of Attention, for cognitive performance; and the Horne and Östberg questionnaire, for identifying the individual chronotype. A daily sleep dairy was kept throughout the 67-day period, in which dancers recorded specific details about their sleep. An actigraph was worn throughout the test period to record participant's activity and to calculate (together with the sleep dairy) both the sleep-time and activity-rest indexes. Results indicated a decrease in sleep efficiency and sleep duration over the test period, which was marked by high physical and mental stress. Sleep duration was already lower than the norm at the start of the study. While the time to fall asleep and subjective ratings in sleep quality and duration showed no changes, a significant decrease in concentration performance score was found. Dancers with lower sleep quality scores also had lower mental health reports. Time in bed was inconsistent through the period, but did decrease in the week before the premier.

The insufficient physical preparation for performance and the consequences of performance schedules on sleep cycles may have further implications related to overtraining and the relation thereof to injuries (Brink et al., 2012; Rodrigues-Krause et al., 2015a). Koutedakis et al. (1999) suggested that dancers were overtrained at the end of the year as they performed better on fitness testing after a non-active holiday period. Seventeen female ballet dancers were tested before and after a six-week holiday break. Little physical activity was reported during the break, marking it as a rest period. Follow-up results indicated an increase in three flexibility tests (15%), peak anaerobic power (14%), leg flexion and extension strength (16%), and maximal oxygen uptake (VO_2max) (10%). Koutedakis et al. (1999) concluded that the dancers were overtrained before the break and that the six-week interval provided sufficient time for recovery.

Additionally to shortcomings in the training regimes of ballet dancers, the great pressure put on dancers, especially female dancers, in regards to physique has also been associated with injury. Micheli et al. (2005) reported an increased demand for thinness in ballet dancers over the past 12–18 years by referring to the decrease of dancers' body fat percentage (BF%). A significant positive correlation between restricted energy intake due to demand for thinness and injury has been reported (Liederbach & Compagno, 2001). The duration of injury rehabilitation has also been found to inversely correlate with BF% in ballet dancers (Twitchet et al., 2008; Twitchett et al., 2010a). Discussion of these studies will follow. All the studies below used the four-site skinfold measuring technique for BF% calculations.

Micheli et al. (2005) compared recent professional ballet dancers' pre-season body fat percentage results (male, 6.5%; female, 12.8%) from a single company with that of a 1984 study (Micheli et al., 1984) carried out at the same company (BF%: male and female, 15.7%). Descriptors of the dancers included are as follows: male, 29: age 24 ± 5.5 years, weight 71.6kg ± 6.4kg. Female, 39: age 22 ± 3.8 years, weight 51.6kg ± 4.6kg. Professional dancing years: 1–20 years; performance level: 20% principals, 13% soloists, 46% corps de ballet, 21% apprentice. Seven-site skinfold thickness measurements were taken using a skinfold calliper to calculate the BF% of each dancer. Micheli et al. (2005) reported a consistent decrease in BF% of the female dancers over a nine-month season (pre-season 12.8 ± 2.7%, post-season 11.5 ± 2.1%). In contrast to this, male dancers showed no significant changes over the season (6.5 ± 2.7% to 6.8 ± 2.8%). The decrease in BF% in women over a performance season could be due to an increase in training load without an increase in calorie intake to meet the increased energy demands. Alternatively, it could be because calorie intake has been further restricted over the season. The authors stated that these results of body composition are, however, in line with elite athletes in various sports.

Restriction in energy intake could cause reduced energy reserves leading to more rapid muscle fatigue (Jeukendrup & Gleeson, 2004). Liederbach and Compagno, (2001) (discussed previously in detail) found 69% of the ballet dancers in their study were dieting to lose weight during the time of injury. Restrictive energy consumption in female ballet dancers has been shown to be as little as 70% in students and 80% (Dahlström et al., 1990) in professional dancers (Benson et al., 1985).

Twitchett et al. (2010) included 13 elite female ballet dancers' monitored over 15 weeks and reported a significant negative correlation between duration of modified activity after injury and BF% (r=-0.614, p=0.026). Twitchet et al. (2008) included 42 full-time ballet students (sex: 31 female, 11 male; age: 17.3 ± 1.02 years) from two vocational dance schools. They collected injury data retrospectively using a questionnaire in which the participants were asked to describe injuries of past 12 months. They too reported a significant negative correlation between total time off due to injury and BF% (r=-0.31; p=0.048) and time off due to acute injury specifically and percentage body fat (r=–0.32; p=0.04).

In the section above, a relationship between fatigue and injury risk has been shown. It is important to re-emphasise that fatigue is multi-dimensional and could occur on a physical and psycho-emotional level. Taking the demands placed on ballet dancers into consideration, recovery becomes an important aspect to address. Recovery will be discussed in the following section.

D. RECOVERY

Ballet dancers experience increased levels of physical fatigue throughout a season. High levels of fatigue are regarded as a primary risk factor for injuries in ballet dancers. Kenttä and Hassmén (2002: 58) described the athlete as a “psychosociophysiological entity”. It is therefore evident that a number of factors can cause different types of fatigue in ballet dancers, not only physical and physiological fatigue. Fatigue can be categorised into three main categories namely; neuromuscular, neuroendocrine and metabolic (Tudor, 1999:120). Within the context of the current study, subsequent references to fatigue imply all types of fatigue from a holistic perspective. Understanding the recovery process and implementation has become an important aspect in possibly lowering injury risk in dancers. Recovery is defined as “…a multifaceted… restorative process relative to time.” (Kellmann et al., 2018:240).

Fatigue-recovery continuum

Fatigue and recovery are on a continuum and are influenced by physiological and psychological stressors (Kellmann et al., 2018). The balance between fatigue and recovery can be influenced by manipulating the amount of stress (e.g. training load) and recovery to prompt specific physiological and psychological adaptations. The training phase and the objectives of that phase will determine the emphasis on either recovery or training overload (Halson, 2014a; Kellmann et al., 2018). Kellmann (2010) describes the position of an athlete on the fatigue-recovery continuum with the Recovery-Stress State (REST) model. This model reflects the balance between all stressors and recovery interventions affecting an individual at a specific time. The balance between recovery and stress is fundamental for optimal performance and will from now on be referred to as the ‘recovery-stress state’ of an athlete.

A degree of fatigue is necessary for positive performance adaptation (Kellmann et al., 2018). This degree of fatigue is achieved by a training overload, which results in a temporary decrease in performance. With sufficient rest and recovery, benefits of the acute overload will be achieved within two to 14 days, referred to as Functional Overreaching (FO) (Lewis et al., 2009; Tudor, 1999). If the balance between fatigue and recovery is not restored with sufficient recovery after FO for a prolonged period of time, the chronic imbalance can lead to negative adaptations. These negative adaptations can include underrecovery and non-functional overreaching (NFO) (Carfagno & Hendrix, 2014; Kellmann et al., 2018). Non-functional overreaching is distinguished from FO by the time it takes the athlete to recover from a reduced performance state, not in terms of the severity of the symptoms present (Kreher & Schwartz, 2012). Recovery from NFO will take several days to weeks (Kreher & Schwartz, 2012) to restore performance as opposed to the shorter time needed for FO.

Similar to NFO, underrecovery also results in a decrease in performance. However, the causes and characteristics thereof are different. Non-functional overreaching is related to changes in training-specific psychological and hormonal factors (Meeusen et al., 2013), while under-recovery refers to a neglect of recovery in response to general (lifestyle) stress (Kellmann et al., 2018). Chronic training and competition stress (NFO) and training errors (Smith & Norris, 2002) in combination with lifestyle stress has been found to be a precursor to the development of overtraining syndrome (OTS) in dancers (Kellmann et al., 2018).

Overtraining syndrome results in chronic performance decrements and psychological and physiological symptoms are not necessarily present (Carfagno & Hendrix, 2014). The reduction in performance and other symptoms caused by OTS may last for anything from several months to years. In this state, rest is no longer sufficient to reverse the negative training adaptations (Myrick, 2015). Carfagno and Hendrix (2014) stated that many European physicians and researchers use the term “Unexplained Underperformance Syndrome” (UUS) or “underrecovery” (Kellmann et al., 2010) instead of OTS. Kellmann (2010) argued that UUS might be better accepted by coaches, as there are multiple non-training-related factors that also contribute to this negative state. This term releases coaches from the notion that the blame rests solely on them and their coaching programme.

The scissors-model by Kallus and Kellmann (2000) (Figure 2.1) illustrates the effect of stress on the recovery demand and how a prolonged imbalance can lead to OTS. The recovery-stress state illustrated in Figure 2.1 below occurs on a continuum of increasing training load. On the right end of the continuum is “overtraining” and on the left is “no training”. A greater amount of stress placed on an athlete, requires a greater amount of recovery to keep a positive stress-recovery balance. In other words, the more overtrained an athlete becomes, the more recovery efforts are needed to restore the balance. Recovery is a regulator of the balance and therefore increases in stress (training- and lifestyle-related) are only detrimental if recovery is not sufficiently applied. In the case where stress increases above the individual's natural capacity of optimal recovery, it will be necessary to introduce additional recovery activities to meet the recovery demands Kallus and Kellmann (2000).

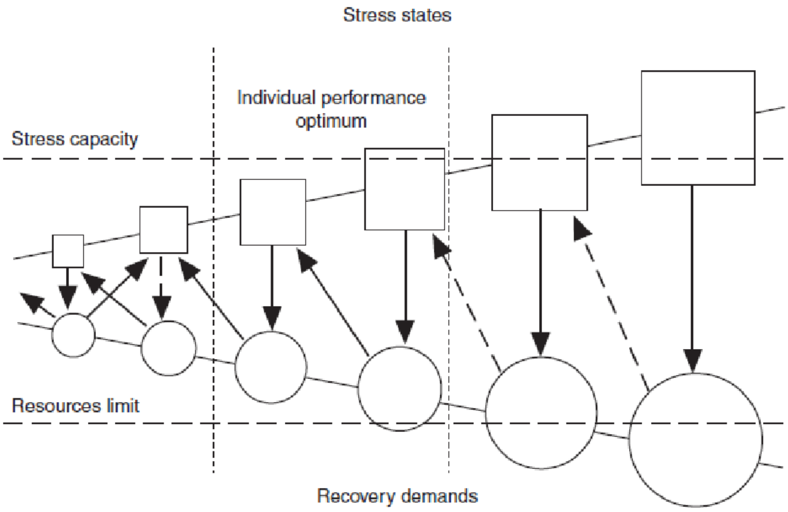


Figure 2.1 **Scissors-model illustrating the influence of recovery and stress on the recovery-stress state to indicate the development of overtraining syndrome. Reprinted, by permission, from Kallus & Kellmann (2000).**

Assessing and monitoring recovery state

Fatigue, as a result of, and in combination with training load monitoring, can be monitored to quantify the athlete's recovery state (Heidari et al., 2019). Due to the many factors influencing the recovery-stress state, it is crucial to approach the monitoring and assessment of recovery in a multidimensional way.

Each individual copes with and reacts to stressors in a unique way, and each individual will experience unique stressors dependent on the type and duration of a stress to which they are exposed. The individual's physiological and training status, and specific situational conditions also influence fatigue. Recovery is thus inter-individual and intra-individual specific (Kellmann & Kallus, 2001). Since each athlete and their situation is unique, it is recommended that any a monitoring tool used should take into account a wide range of possible stressors. In addition to this, continuous monitoring is advised, as this will assist in determining the most sensitive aspects of the specific individual's coping abilities (Kellmann, 2010). Continuous monitoring is also recommended due to the dynamic changes in fatigue-recovery state and its sensitivity to daily alterations in stressors and recovery (Filho et al., 2015). A holistic monitoring approach is therefore recommended. Additionally, assessments should be sport-specific, taking into consideration the demands of the sport at hand (Kellmann et al., 2018).

Multiple assessment and monitoring strategies have been used to determine an athlete's recovery-stress state. Assessment can be either an objective approach (including physiological and/or performance measures), subjective approach (including psychological and/or sociological measures) or a combination of the two approaches (Heidari et al., 2019; Kellmann et al., 2018). For the purpose of the current study, the emphasis has been placed on assessment methods relating to subjective approaches in monitoring recovery-stress states of dancers. However, the following sections will make mention of objective monitoring and assessment approaches to recovery states.

Objective approaches

Physiological markers are objective indicators of the disruption training loads have caused in the body (Kellmann et al., 2018). Certain methods involve taking measures at rest (e.g. blood markers, HR) and other during exercise (e.g. oxygen consumption (VO_2)) heart rate response (HRR)) (Saw et al., 2016). Blood-based variables have been used including blood lactate, creatine kinase, urea nitrogen, salivary cortisol, free testosterone and/or insulin-like growth factor-1 (IGF-1). Some of these have been shown to be more accurate than others (Kellmann et al., 2018). These methods are often expensive, time-consuming and require a medical professional to take the sample and analyse the results. However, another physiological method that has been used with great success is the measurement of HR, HR reserve (HRR) and/or HR variability (HRV) at rest or after exercise to monitor the autonomic nervous system (Halson, 2014b). Advantages of this method are that it can be applied to large groups, it is time-efficient, non-invasive and affordable (Burgess, 2017). Diurnal factors, food and fluid consumption, and activity should be taken into consideration before monitoring HR, as HRV values are extremely sensitive to these factors (Burgess, 2017).

Performance assessment is another objective measure of fatigue (Heidari et al., 2019). The most specific performance measure to a sport code is the competition outcomes. However, for this assessment method to be used, sport-specific gold standards are required for the variables measured by means of a maximal sport-specific test (Kellmann et al., 2018).

Subjective approaches

Psychological assessment are subjective and reflect the individual's perceived recovery status in reaction to chronic and acute training load (Heidari et al., 2019; Kellmann et al., 2018; Saw et al., 2016). Three of the most commonly used questionnaires in practice for this assessment method are the Multicomponent Training Distress Scale (MTDS), the Profile of Mood States (POMS) and the Recovery-Stress Questionnaire for Athletes (RESTQ-Sports) (Saw et al., 2016). Psychological means of measure have the advantage of being both affordable and sensitive (Kellmann et al., 2018). Saw et al. (2016) recommended the use of subjective well-being monitoring instruments on a regular basis.

Sociological assessment is best approached with psychometric measures or questionnaires followed by direct communication for a more detailed insight (Heidari et al., 2019). Two appropriate questionnaires that could be used for this method are the RESTQ-Sport questionnaire and the Daily Analysis of Life Demands for Athletes (DALDA), which measure the symptoms of stress (Heidari et al., 2019).

Although certain methods have shown to be reliable and accurate, not all can practically be applied in a large athlete group on a long-term basis. Saw et al. (2016) state that subjective measures are more sensitive and consistent in reflecting acute and chronic training loads than objective measures. The authors reviewed 56 original studies to compare subjective and objective methods of well-being and their response to acute and chronic training load. In that study, Saw et al. (2016) recommended the use of a daily self-administered measure, supplemented by a more comprehensive measure (e.g. RESTQ-Sport or POMS) on a weekly basis and an objective measure on a once-per-training microcycle basis.

In dance companies specifically, Armstrong (2019) confirmed the limited amount of psychometric screening applied in the dance setting. In his study, he reported on the current screening practices used in dance companies or schools and university dance programmes. Thirty-two individuals (mostly physiotherapists and dance teachers) were involved in dance screening and completed the Bristol online survey. Only nine out of 32 individuals used psychometric tests to measure anxiety, general mood state and depression. None of the psychometric tests have been used by more than one respondent. The POMS, Dimensions of Anger Reactions (DAR), State-Trait Anxiety Inventory, and six depression screening questionnaires were some of the questionnaires used.

For the purpose of this study, the researcher focused on monitoring methods that could be implemented specifically in a dance company setting and over an extended period of time. Feasibility, time efficiency and simplicity were key requirements of the methods investigated for use. POMS and RESTQ-Sport questionnaires both adhered to these requirements and consequently dance studies who utilised either of these questionnaires were further investigated. Only a few studies were found within these requirements therefor it was inevitable to include studies on sport codes. The few studies on dancers, either assessed dancers' recovery-state once off or for a short duration of time (nine days).

The POMS questionnaire reflects an athlete's response to training load and other stimuli (Kellmann et al., 2018). The questionnaire consists of 65 questions and assesses six aspects over a previous week of training, namely: tension, anger, depression, fatigue, confusion and vigour (McNair et al., 1992). The questionnaire has been used in a wide variety of sport codes, however only a few ballet research studies implementing the POMS questionnaire were found. All of these studies investigated the association of psychological factors with injuries (Adam et al., 2004; Liederbach & Compagno, 2001). In two studies, the POMS questionnaire was supplemented with additional psychological measurement questionnaires including the Perceived Stress Scale, Social Support Appraisal Scale, Pittsburgh Sleep Quality Index and the Eating Disorders Inventory 2. The three studies are summarised in Table 2.4 on the following page and discussed in more detail below.

Adam et al. (2004) reported significant ($p<0.05$) positive correlations between absence due to injury and perceived stress. In addition to this, the authors found significant positive correlations between injuries and several mood states, including tension, depression, anger, confusion and fatigue. A significant negative relationship between injuries and social support and vigour-activity was reported. Liederbach and Compagno (2001) (discussed under Injuries and related burdens of ballet dancers, section C) found that dancers with one or more injuries scored significantly higher on the fatigue item on the POMS questionnaire at the start of the study compared to the non-injured dancers.

Two of the studies investigating the relationship between stress and injury implemented the POMS questionnaire. This was done only once, at the start of the study (Adam et al., 2004; Liederbach & Compagno, 2001). Injuries were defined by being exempt from part or classes, rehearsals or performances. Both studies provide evidence of the significant positive correlation between fatigue at the beginning of a season and subsequent injury. In addition, Liederbach and Compagno (2001) also found significant positive correlations between injury and specific fatigue reports taken at the time of injury. This supports the suggestion that monitoring should occur on a continuous basis and not only as a screening tool at the start of the season. Such continuous monitoring will alert health practitioners and company staff of individuals at high risk for injury at any time of the season. In accordance with the other two studies, Liederbach et al. (1992) also found a significant relationship between fatigue reported on POMS with injury occurrence.

Table 2.4 Studies that used the POMS questionnaire in a dance population.

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Adam et al. (2004)	54 professional ballet dancers, n=54 (female, 30; male, 24) mean age: 26.59 ± 6.2yrs	Quantitative and qualitative Questionnaire battery completed once at the same time as the structured interview for injury history of the preceding nine months	- POMS - Cohen Perceived Stress Scale - Social Support Appraisal Scale - Pittsburgh Sleep Quality Index - Injury history interview - Percentage of performance and rehearsal days missed due to injury	Emphasised the necessity of including assessment and treatment of psychological variables (e.g. stress, sleep problems, negative mood states) in dancers' programmes in an attempt to reduce injury rate.
Liederbach and Compagno (2001)	University and professional ballet dancers. N=644 dancers University: n=282, age 19.7 ± 2.2 yrs, 68% female, 32% male Ballet company: n=123, age 24.6 ± 4.9yrs old, 56% female, 44% male Clinic: n=239, age 27.8 ± 8.0yrs old, 78% female, 22% male	Longitudinal study over a two-year period. 500 dance injury reports completed at time of injury -POMS and EDI-2 completed at start of study	- POMS - EDI-2 - Injury report including environmental factors at time of injury	Found that dancers were more susceptible to injury where self-reporting indicated fatigue, an increased training load, high intensity or monotonous training as well as changes in mood and/or diet.

Liederbach et al. (1992) (study unavailable)	12 professional ballet dancers (6 male; 6 female)	Longitudinal prospective study over a five-week performance season. Data collected weekly	- POMS - Urinary excretion of free norepinephrine and epinephrine	Found that self-reported scores for fatigue on POMS correlated significantly with injury onset and urinary catecholamine levels.

Kellmann and Kallus (2001) suggested that the POMS questionnaire may be insufficient in evaluating the recovery-state of an athlete since it includes only responses to stressors, not recovery questions. As discussed above, recovery is a critical part in the recovery-state and is not merely the absence of stress, but also a proactive individualised process (Kellmann & Kallus, 2001). The RESTQ-Sport reflects on various stress and recovery scales representative of sport-specific and general origins respectively (Kellmann et al., 2018). The RESTQ-76 Sport questionnaire was developed by Kellmann and Kallus (2001) to systematically measure the recovery-stress states of athletes by referring to the physical and mental impact of training stress. The RESTQ-76-Sport consists of 19 subscales, which can be grouped in four major subscales, i.e. 12 general stress and general recovery scales, and seven sport-specific stress and recovery scales (Appendix A). The questionnaire has been shown reliable for test and retest over a 24-hour period (r>0.79) and valid (Kellman & Kallus, 2001). This questionnaire remains reliable for up to four-week intervals (Kellman & Kallus, 2001). Saw et al. (2016) reported that RESTQ-Sport was the only self-report measure that was reflective of both acute and chronic training load in their study.

The RESTQ-Sport questionnaire has been used in variety of different sport codes and is commonly used to monitor elite athletes. These sport codes include players from basketball, volleyball and korfball (Van der Does et al., 2017), cyclists (Filho et al., 2015), swimmers (Zanini et al., 2018) and rhythmic gymnasts (Codonhato et al., 2018). In the study on basketball, volleyball and korfball, male and female sub-elite athletes were monitored over a period of 41 weeks and completed the RESTQ every three weeks. The RESTQ questionnaires were used as a possible prediction method for acute and chronic injuries. A decrease in general recovery (GR) six-weeks prior to acute injury and a decrease in sport recovery three-weeks prior to overuse injury were noted. Athletes showed a significant decrease in three GR scales: social recovery, general well-being and personal accomplishment over both three- and six-weeks prior to injury. Changes in perceived stress did not correlate with injury occurrence.

In a multi-stage cycling event, 67 professional cyclists were monitorred twice over 10 days (nine stages) (Filho et al., 2015). Filho et al. (2015) investigated the correlation between recovery-stress factors and performance at the start and end of the race. RESTQ reports were collected at the beginning of the race and prior the last stage, while a subjective performance rating was collected after both the first and final stages. In stage 1, physical recovery, injury and general well-being predicted performance. In the final stage, performance correlated positively with conflicts/pressure and negatively with lack of energy. Only the "being in shape" and "self-regulation" scales had a strong correlation in both stages.

Zanini et al. (2018) monitored 32 swimmers in four instances over both a preparation and performance season to describe the change in mood and stress-recovery states. The time point of only three testing instances was stated in the article. At the start of the preparation period, the athletes were in high moods. This was the only time point where the group's recovery-stress profile represented the Iceberg profile indicative of positive mental health. As time progressed, general stress (specifically tension, depression, anger, fatigue and confusion) increased, and general and sport-specific recovery (specifically vigour) decreased. Measurement three showed the most unfavourable Total Mood Disorder score, however it is not clear form the article at which time point in the season this measurements was taken.

Eight professional rhythmic gymnasts (Codonhato et al., 2018) were monitored over a year in preparation for the Olympic Games. The study examined the relationship between stress states, resilience and injuries. RESTQ was collected four times, each time one week before a competition. The resilience questionnaire was collected at the beginning and end of the investigation, and injury reports were gathered throughout the year. RESTQ scores were relatively stable throughout the year and recovery was significantly higher than stress at all four measuring instances. No significant correlation was found between resilience and total stress or total recovery at any of the four points.

In these studies, RESTQ scales were predictive of injury occurrence as well as performance in various sports. They support the usefulness of the RESTQ-Sport in monitoring and consequentially taking precautions to lower the risk of overtraining and injury in athletes. Table 2.2 on the next page, provides a short summary of the mentioned studies.

Table 2.5 Studies using RESTQ-Sport in different sport codes.

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Van der Does et al. (2017)	86 sub-elite athletes (58 male, age: 22.1 ± 3.8 yrs; 28 female, age: 21.5 ± 2.5yrs). Sports: basketball (26), volleyball (38), korfball (22)	Monitored athletes over a 41-week season. RESTQ completed every three weeks	- RESTQ-Sport 76 (Dutch version) - Injury reports	Recovery-enhancing practices are deemed important to address in injury risk management.
Filho et al. (2015)	67 professional cyclists (age: 21.9 ± 1.6; cycling experience 11.23 ± 5.90yrs)	Monitored over a 10-day period. RESTQ collected at the beginning and prior the last stage of a nine-stage cycle race Performance rating collected after stages 1 and 9	- RESTQ-Sport - Subjective performance rating (1–10 likert scale)	The recovery-stress state changes greatly over a short period of time and dynamically influence an athlete's performance during a multi-stage competitions
Zanini et al. (2018)	32 swimmers (male and female; age: 21 ± 7yrs) monitored over a season.	Longitudinal study. Data collected on four instances from start of preparation phase to end of competition phase.	- RESTQ-Sport 76 - Brunel's Mood Scale (BRUMS) - sRPE	Athletes show progression in unbalanced mood and recovery-stress states as the season progresses, placing the athletes at an increased risk injury and overtraining.
Codonhato et al. (2018)	8 female (mean age of 20.4 ± 2.5yrs) participants of the	Mixed methods (quantitative and qualitative)	- RESTQ-76 Sport (Portuguese) (4X) - CD-RISC-10 (2X)	Social support was considered the main psychological factor for the resilience process. Injury

	Brazilian rhythmic gymnastics Olympic team.	Longitudinal across the season (13 months)	- Physical therapy records - Structured qualitative questionnaire	rehabilitation and stress control are influenced by resilience in elite rhythmic gymnasts.

Note: (4x), (2x) = questionnaire was implemented four times or two respectively during the testing period; CD-RISC-10 = Connor-Davidson Resilience Scale, yrs = years

Table 2.6 Studies on dancers using the RESTQ-Sport.

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Edmonds et al. (2018)	29 female collage dance students (predominantly modern and ballet), age: 20.0 ± 1.1yrs old	Nine-day dance performance period. Data were collected on five different occasions.	- RESTQ-Sport (53) [scales reported: self-efficacy, general stress, fatigue and general well-being] - HR variability (HRV)	The increase in self-efficacy scores might indicate dancers are more comparable to athletes than other artists with regards to performance readiness. They emphasised the necessity of a long-term study to investigate how dancers cope with the stressors of a dance semester.
Da Silva et al. (2016)	Adolescent Brazilian ballet dancers, n=264 (255 female, 18 male; mean age: 14.69yrs)	Data collection took place once off at national and international levels of dance festivals.	- The RESTQ-Dance 63 was developed from the RESTQ-76 Sport	Concluded that the RESTQ-Dance 63 questionnaire are valid to use in the dance population.

Note: HR = heart rate, HRV = heart rate variability, yrs = years

It would seem that the use of RESTQ in dance is limited in English published literature. The researcher found only two dance studies using the RESTQ-Sport questionnaire (Edmonds et al., 2018) (da Silva et al., 2016). For da Silva et al. (2016) only the abstract was available in English. Table 2.3 contains a summary of these studies.

The RESTQ-53 was used in an attempt to test performance readiness of female collage dance students (in combination with HRV measurements) (Edmonds et al., 2018). Data was collected on five occasions over nine days of training and performances. Tests were completed on the morning of the first and last days, before rehearsal and two performances. Only certain RESTQ scales were reported. Self-efficacy increased significantly after the first show for the remaining two readings. General stress was highest prior to the dress rehearsal, but was only significantly higher when compared to the second pre-show reading. No significant fluctuations were seen in either the fatigue or general well-being scales.

The second study was a validation study for an adapted RESTQ-Sport questionnaire, RESTQ-Dance (da Silva et al., 2016). The RESTQ-Dance questionnaire has 63 questions divided into three main categories. Da Silva et al. (2016) reported adequate psychometric properties for the use in a dance population. The study included 264 Brazilian dance students at national and international level.

Both studies (Da Silva et al., 2016; Edmonds et al., 2018) included non-professional (adolescents and college dance students) dancers. Different types of dance styles were investigated, including but not limited to: ballet and modern. Da Silva et al. (2016) did not specify the dance style in which the students were trained. Neither of the two studies used the RESTQ-76 Sport and neither were longitudinal studies, as the studies on sport codes reported above. This is surprising, since ample research has recommended the use of this questionnaire in different sport codes for continuous monitoring. Additionally Grove et al. (2013) recommended its use specifically for dance.

Grove et al. (2013) discussed the training distress process with specific reference to the dance population in a model shown in Figure2.2. The RESTQ-Sport addresses four out of the six identified stress scales (sleep difficulties, somatic symptoms, generalised fatigue and perceived stress), compared to the POMS, which measures only two (mood disturbance and generalized fatigue). Grove et al. (2013a) recommended the use of the RESTQ-Sport questionnaire as a monitoring method within the dance population. The authors did, however, point out the disadvantage of the extensive length of the RESTQ-Sport 76 when the goal is to use it over a long period of time**.** Shortened versions of the RESTQ-Sport has since been developed and should be beneficial as it is less time-consuming (RESTQ-53 Sport (Kellmann & Kallus, 2001) and RESTQ-Dance 63 (da Silva et al., 2016)).

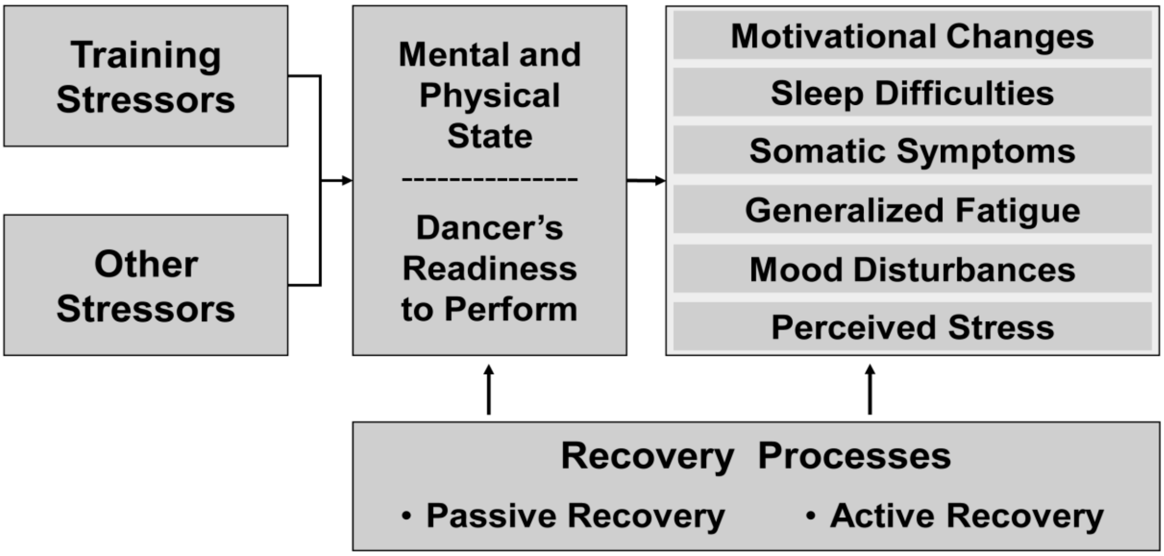


Figure 2.2 Dance-specific Conceptual Model of the Training Distress Process. Reprinted with permission from Grove et al. (2013a).

To summarise, there are limited publications of longitudinal studies conducted on the recovery-states of the dance population, and specifically on professional ballet dancers, in the English literature.

Recovery strategies

Depending on the results obtained during the monitoring of recovery state, more or fewer recovery strategies need to be implemented in athletes' schedules to restore the recovery-stress balance.

Recovery strategies can be subdivided into psychological and regeneration categories (Kellmann et al., 2018). In a sport context, regeneration refers to physiological recovery (Kallus & Gaisbachgrabner, 2017), whereas psychological recovery strategies can be implemented to compensate for mental fatigue. "Effective recovery strategies involve active processes with the aim of re-establishing psych, physio, emotional, social, an behavioural components that will allow the athlete to tax these resources again (Kellmann & Kallus, 2001; Botterill & Wilson, 2002; Noakes, 2003)" (Venter et al., 2010:133-134).

All physiological and psychological stressors that affect performance should be addressed with recovery strategies (Halson, 2013). Halson (2013) listed the following stressors to be taken into consideration to attain optimal recovery: training/performance stress, nutrition, psychological stress, lifestyle, health and environment. Kellmann (2010) categorised stressors into three categories: physical, mental and emotional stressors, or demands from either exercise/sport or lifestyle origin. Three different approaches to recovery can be followed, namely: active, passive and proactive (Kellmann, 2002). Active recovery is the use of physical activity to reverse the metabolic responses of physical fatigue (Kellmann et al., 2018). Passive recovery includes all recovery methods used while physically inactive, either merely resting or by applying external methods (e.g. massage). Proactive recovery is personalised to each athlete's needs and preferences (e.g. social activities) (Venter et al., 2010). In the South African context in which the current study was carried out, it was suggested that the need for education on recovery modalities for coaches and athletes, is increased (Venter et al., 2010).

E. TRAINING LOAD

As discussed above, training load (TL) is one of the aspects that modulate the amount of recovery needed. Monitoring TL is a critical part of training periodisation to ensure optimal preparation for performance or competition, and to reduce the risk for developing OTS (Foster et al., 2001; Haddad et al., 2017). Training load can be divided into two main categories: external load and internal load. External load is an objective measure of the work done by an athlete, while internal load is the estimated physiological and metabolic impact of the work done during a training session (Kellmann et al., 2018). Kellmann et al. (2018) recommended to implement a combination of both internal and external training load monitoring systems.

As fatigue and recovery state are on a continuum and fatigue is in part caused by the TL experienced by the athlete, monitoring the recovery state and training load are closely related and often intertwined. Common training load monitoring methods are listed below and some will be discussed later in this section.

Monitoring training load

Internal training load methods

Session RPE is a subjective method and the most commonly used internal TL measure in team sport research and practice. It is easy to collect, is cost-effective and can quantify TL across training types (Impellizzeri et al., 2004). This method is discussed in more detail below. The rating of perceived exertion (RPE) and session RPE (sRPE) are other popular methods used and measure training intensity and training load.

Heart-rate-derived assessments: HR and the Training Impulse (TRIMP) method are objective, relatively inexpensive and convenient methods to use, particularly in a team sport setting (Alexandre et al., 2012). If the athlete's maximal HR is known, HR can be further individualised by expressing HR as a relative value (Burgess, 2017).

Oxygen uptake: This method requires advanced equipment and expertise, and could limit certain movements. The oxygen uptake has been used in many research studies focused on dancers (Esposito et al., 2004; Guidetti et al., 2007; Jeffries et al., 2017; Schantz & Strand, 1984; Wyon, et al., 2003; Wyon, et al., 2004).

External training load methods

Power-output-measuring devices such as the Global Positioning System (GPS), Accelerometer and force plate are discussed in more detail below.

Video analysis: Analysing the number of times a specific movement is executed allows quantification. This data can then be used to describe TL in conjunction with specific objective information known for that movement. The time motion and match analysis system could be used for this method (Wyon et al., 2011). Video analysis is time-consuming and requires specialised equipment and expertise.

Dance studies who investigated the demands of ballet, have focused on determining the cardiovascular demands and intensity of a single class, rehearsals and, to a lesser extent, performance (Cohen et al., 1982a; Cohen et al., 1982b; Rodrigues-Krause et al., 2014c; Schantz & Astrand, 1984;). Most studies have made use of HR monitoring, oxygen uptake and/or blood lactate measurements. A very limited number of studies have taken a longitudinal approach in attempt to quantify the TL of dancers over a specific training phase or season. The only studies found that investigated dancers' TL over multiple days used either sRPE (Boeding et al., 2019; Da Silva et al., 2015; Jeffries et al., 2017; Surgenor & Wyon, 2019) or accelerometers in combination with HR measurements (Jeffries et al., 2017; Twitchett et al., 2010). These studies will be discussed below and are grouped together by monitoring method. The monitoring methods that was utilised in the current study, will be discussed in detail after which the applicable studies will follow.

Rate of perceived exertion (RPE)

The Borg category-ratio (CR10) Rate of Perceived Exertion scale is widely used to subjectively estimate effort and exertion, breathlessness, and fatigue during physical work (Borg, 1998). It spans from 1–10 with verbal anchors as indicators of exertion and has been found to be a reliable and valid method (Herman et al., 2006) of assessment.

Foster et al., (2001) proposed the session-RPE TL method, which is based on the RPE scale. This method includes both the intensity and the duration of the exercise session. Athletes report a global RPE score (sRPE) after the training session, describing their perceived intensity of the session as a whole. The product of the arbitrary sRPE score and the duration of the session (minutes) gives a single number representative of the internal TL experienced by the individual (Foster et al., 2001). Session RPE was proven to be reliable and valid for a wide variety of training types, including ultra-high intensity exercise (resistance training, plyometrics) (Foster et al., 2001) and skill-based training (TeamGym) (Minganti et al., 2010). In a review article published by Haddad et al. (2017), the validity and reliability of sRPE in both men and woman of various age categories and expertise levels were confirmed for a variety of different sports.

Foster et al. (2001) suggested that the sRPE method might be a valid method for monitoring very high-intensity exercise such as resistance training and plyometrics. According to the authors, this stands in contrast to the HR criteria, which cannot be used to objectively measure ultra-high-intensity exercise. An advantage of the sRPE method is that it can be used without knowledge of the athlete’s maximal exercise responses (e.g. HRpeak) as reference for the collected results (Foster et al., 2001). A good relationship between sRPE TL reports and performance was reported by Foster et al. (1996). In addition, sRPE has shown good intraindividual consistency regardless whether the athletes are globally (including rest periods during a session) or detail-oriented (excluding rest periods) in their reporting approach (Foster, et al., 1996; Foster et al., 2001). Minganti et al., (2010) supported the reliability of sRPE scores including and excluding rest periods during an exercise bout or training session in endurance runners. Both the inclusion and exclusion of rest periods in the session time had a strong correlation with the Edwards’ HR method. No significant difference in correlation was found when comparing different session durations. Consequently, further research regarding including or excluding the rest periods was suggested.

The time lapse between the end of an exercise session and collection of the RPE score must be taken into consideration. It has been suggested that the standard procedure should be to collect a RPE score 30-minutes after the termination of the exercise session to limit the influence of terminal RPE on the overall sRPE score (Tibana et al., 2018). Christen et al. (2016) evaluated the temporal robustness of sRPE by comparing sRPE scores sampled from five minutes to 24-hours post exercise and concluded that sRPE scores are temporal robust. In addition to this the authors found that the time elapsed after the exercise session appeared to have no significant effect on sRPE after either interval or steady-state exercise, provided a cool-down was incorporated into the training session. During ballet training, there is seldom a cool-down present. Hence, studies that investigated the influence of time on RPE scores reported after a training session with no cool-down were taken into account.

Hornsby et al. (2013) showed that terminal exercise intensity has a significant influence on the final acute RPE prior to exercise termination (terminal RPE), but also stated that terminal intensity did not influence the sRPE taken 20 minutes after the termination of training. Tibana et al. (2018) found that the sRPE reported at 0-, 10- and 20-minute intervals after high-intensity functional training (without cool-down) were significantly higher than the sRPE rating reported at 30 minutes post exercise. These results support the argument that sRPE should be reported at least 30 minutes after exercise termination if no cool-down is present, but could still be validly recorded up to 24 hours after termination (Christen et al., 2016).

The sRPE method (Foster et al., 2001) has been recommended to monitor TL in dancers (Jeffries et al., 2017; Surgenor & Wyon, 2019; Wyon, 2014). Only four studies could be found where sRPE was used to quantify internal TL in a ballet, modern or contemporary dance population. The studies are summarised in Table 2.7 and are reported in more detail below (Boeding et al., 2019; Da Silva et al., 2015; Jeffries et al., 2017; Surgenor & Wyon, 2019). Two of these studies validated the sRPE in the dance population, specifically for contemporary and ballet dance (Jeffries et al., 2017; Surgenor & Wyon, 2019).

Surgenor & Wyon (2019) reported a strong positive correlation between sRPE and Edwards-RL methods of TL monitoring in ballet dancers (ballet class: r=0.46, p=0.018; rehearsal sessions r=0.74, p=0.001). Jeffries et al. (2017) reported the validity of sRPE in ballet as training load and training intensity measure. Within-individual and group comparisons were made between sRPE, HR measures, accelerometer variables and pain reports. Session RPE TL correlated significantly with other measures of internal TL (r=0.69-0.77). The authors reported large to very large within-individual correlations between sRPE and various accelerometer-derived measures of external TL. Ballet (r=0.32-0.58) revealed poorer, although still a large, correlations between sRPE TL and various load constructs compared to contemporary class and contemporary rehearsal. They reported large group correlations in ballet between sRPE TL and Edwards TRIMP (r=0.51), vector-magnitude counts (r=0.40) and %HRpeak (r=0.49). Of the variation in sRPE TL, 49.7% could be explained by %HRpeak, motivation, soreness, metabolic equivalents (METs) and sleep quality. Ballet session TL and intensity results were as follows: session duration = 90.3 ± 23.6min; sRPE TL = 90.0 ± 23.6AU; sRPE = 4.6 ± 1.6AU; Edwards TRIMP =1 04 ± 29AU; vector-magnitude counts (mean) = 170.198 ± 100.779; vector-magnitude average counts = 64 ± 36.

Boeding et al. (2019) concluded that no statistically significant association was found between sRPE TL and SEFIP scores (symptoms of overuse injury) (p=0.127). They did however, find that dancer with pain scores of 0 (no symptoms) reported lower TL than dancers with scores >0. No specific values were reported for TL, but a diagram was presented with the mean weekly TL. Estimated TL averages range between 2500AU and 4750AU per week.

The two tables on the following page provide a summary of the studies published in English literature on dancers who utilised sRPE (Table 2.7) and HR recordings (Table 2.8) to describe training loads and intensity in dancers.

Table 2.7 Dance studies using session RPE

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Surgenor and Wyon, (2019)	10 dance students (4 male, age 20 ± 1.16yrs; 6 female, age 20 ± 0.52yrs)	Five days of classes 96 sessions including: professional ballet and contemporary both classes and rehearsals	- Borg CR-10 [sRPE RL, 15min after session) - Polar Team System HR monitors (5sec intervals) - (Edwards-RL method) -	Recommend the use of sRPE as a valid, affordable, simplistic and technology-free means of TL monitoring in dancer companies.
Jeffries et al. (2017)	16 elite amateur contemporary dancers (5 male, age 18.8 ± 2.4yrs; 11 female, age 19.0 ± 2.0yrs)	Prospective longitudinal research design data were collected during a 49-day period with ballet and contemporary classes and contemporary rehearsals. HR training zones was determined for each dancer. TL measured with HR, waist accelerometers, sRPE reports.	- Borg CR-10 [sRPE TL, 10 minutes after session] - Polar HR transmitter [5-second intervals] - GTX3 ActiGraph [sleep, external load, METs, EEE; 1sec sampling rate at 100Hz] - YIRT [HRmax] - Psychometric questionnaire [before class daily; perceived fatigue, pain, motivation, general muscle soreness, overall recovery] - 2 TRIMP methods (Banister, modified Edwards)	Confirmed the validity of sRPE's usage to quantify TL in dance. A combination of different factors (sleep, internal, external and perceptual) best predicted sRPE TL instead of a single measure. Strain, monotony and TLs were very high.

Da Silva et al. (2015)	27 pre-professional classical ballet dancers (6 female, age 12–15yrs)	Longitudinal descriptive study design. Pre and post-tests over a 17 weeks training period.	- Borg CR-10 [sRPE TL, 30min after session] - Body composition - HR monitor - Anthropometry	Compared to different sports, ballet dancers' training monotony were lower and strain were similar to young female elite athletes. Difference in TL between levels of performance. Inter-week fluctuations in TL.
Boeding et al. (2019)	21 professional contemporary dancers (11 male, age 24.9 ± 1.5yrs; 10 female, age 27.5 ± 2.2yrs)	7 weeks, daily reports on training intensity including dance practice, performance and additional training.	- Borg CR-10 [sRPE TL, one score at end of day] - SEFIP [1x per week]	Conclusion that no statistically significant association was found between sRPE TL and SEFIP scores. Dancers without musculoskeletal pain reported lower TL.

Note: METs = metabolic equivalent of task, EEE = estimated energy expenditure, YIRT = Yo-Yo Intermittent Recovery Test Level, yrs = years

Table 2.8 Dance studies utilising heart rate methods

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Cohen et al. (1982)	13 professional ballet dancers (6 male, 7 female; 1 principal dancer, 5 soloists, 7 corps de ballet)	Monitored dancers during a performance.	- Radiorelemetry (Narco Bio-Systems) - Two chest electrodes - Age predicted HRmax calculated	HR response during stage performance was similar to centre floor practise in class and that the emotional anticipation of live performance might only affect HR slightly
Redding et al. (2004)	19 professional modern dancers (7 male, age 25 ± 4.4yrs, 12 female, age 25 ± 4.0yrs)	Comparing results of a 90-minute modern dance class with that of a modified multi-stage graded treadmill test on the same day.	- PAR-Q form - HR monitor - Portable gas analyser (Cosmed K4 b2 telemetric) - Progressive graded TM test	HR is not a valid prediction method for oxygen consumption as dance is an intermittent activity and cannot be based on the HR-VO_2 relationship established by a steady state laboratory test.
Rodrigues-Krause et al. (2014c)	12 advanced female ballet dancers (age 20.5 ± 3.2yrs)	Assess cardiorespiratory responses, muscle damage and oxidative stress levels during a ballet class and rehearsal respectively. Data collection: a) baseline testing (VO_{2max}), anthropometry, b) class session, c) rehearsal session. Dance sessions 45 minutes	- Incremental treadmill test (VO_{2max}, HRmax, ventilatory thresholds) - Finger prick blood lactate samples - Video recording of sessions - Stadiometer, Filizola scale, Lange caliper	Concluded that both average and peak VO_2 and HR, as well as blood lactate indicated rehearsals were executed at a higher intensity than classes.

		each. One week apart. HR measured every 15 seconds.		
Rodrigues-Krause et al. (2014a)	12 advanced female ballet dancers (age 18.5 ± 2.5yrs),	Cardiorespiratory demands of 9 isolated ballet exercises, each 48 hours apart: a) Body composition assessment (4 skinfolds, height, weight), b) ballet movement performance. Exercises: barre and center floor. Each performed left and right side, separated by 5 minutes of rest c) VO_2 testing.	- Stadiometer, Filizola scale, Lange caliper - Gas analyzer [HR 15 sec increments, VCO_2/VO_2 continuously) - Incremental treadmill test (VO_2 max evaluation) - Metronome	HR may overestimate training intensity due to the intermittent nature and isometric muscle contraction components of ballet. Ballet exercises are low-moderate according to VO_2, and moderate-high according to HR.
Wyon et al. (2004)	40 modern graduate, university and professional dancers (male and female, age 22 ± 3.7yrs)	Oxygen uptake and heart rate of modern class, rehearsal and performance.	- Heart-rate monitor - Telemetric gas analyser - Video recording of session	Performance showed significantly greater mean oxygen uptake and HR compared to class and rehearsal.
Wyon et al. (2002)	27 modern dancers (7 male, 20 female, 10 university students, 7 graduate performers, 10 professional dancers)	Comparing oxygen uptake, heart rate and work to rest ratio of different levels of modern dancers during class.	- Heart-rate monitor - Telemetric gas analyser - Video recording of session	Mean HR and VO_2 did not differ significantly between the levels, but differed between warm-up and center work. For all levels, more time was spent dancing during warm-up than during center work.

Global positioning system (GPS) tracking device and accelerometer

A GPS tracking device is used to monitor athletes during training or competition to evaluate external TL. This method is more practical and time efficient than video analysis and is the most popular method for monitoring external TL in team sports (Beato et al., 2018). The GPS unit can record multiple variables simultaneously in order to quantify the external load parameters. Subsequently, a training profile for a specific athlete-position can be created or TL can be adjusted to ensure the athlete stays on target with the periodisation schedule. The device monitors and stores data that can be analysed at a particular moment or at a later stage.

Global positioning system trackers are predominantly used in outdoor team (football, American football, rugby, hockey) and track (athletics) sports. Recently, they have come into favour in indoor court sports (Cormack et al., 2014). There are various brands of GPS trackers in the sporting industry with varying validity. The validity and reliability of a GPS model depends on multiple internal facets and can range from a very affordable, but less accurate to highly sophisticated devices used in professional sporting teams. Multiple GPS validity, reliability and accuracy studies have been carried out in sport (Beato et al., 2018; Roe et al., 2017), reporting that a higher GPS sampling frequency (10–15Hz) is more accurate than a lower sampling frequency (1–5Hz) (Scott et al., 2016). It is also recommended that the same GPS unit and software are used for a specific athlete for repeated testing to improve accuracy (Roe et al., 2017).

The GPS tracker consists of a pod enclosing a GPS, tri-axial accelerometer, magnetometer and gyroscope. The pod is held in place by a harness in the size best suited to the athlete. When used indoors, the accelerometer is used to estimate the speed and distance travelled based on the footstep impacts of the athlete (STATSports®, 2019). The accelerometer works independently from the satellite system to record impact and body load, which enables data to be collected outdoors as well as indoors (Scott et al., 2016).

To the researcher's knowledge, no study has been carried out monitoring dancers using a GPS tracker. Dance training is done indoors and does not consist of travelling extended distances or exerting high-speed travel over at least a few meters at a time. This limits the GPS variables that may accurately depict the external load dancers experience during training and performance. Looking at acceleration, deceleration and distance run may not be an accurate representation of the demands of dance (ballet). Ballet, however, does involve many jumps. Based on this, impact load could be an important variable to assess during ballet training.

Impact stress

Repetitive impact load, such as repetitive jumps, has been correlated to overused lower limb injuries, including stress fractures (Brockwell et al., 2009; Ekstrand & Torstveit, 2012). Jumping is a big part of ballet performance (Wyon et al., 2006). However, only a few studies describing ground reaction forces (GRF) or impact load associated with ballet specific steps could be found. Ground reaction forces of ballet-specific movements, measured with a force plate, has only been measured and documented in isolation and as part of a short sequence. To the researchers' knowledge, only one published study (Jeffries et al., 2017) has documented the impact load (as vector magnitude) of an entire day's dance training with the use of an accelerometer, including contemporary and ballet styles. Jeffries et al. (2017) are included in Table 2.7 above.

Table 2.9 on the following page contains a summary of the limited number of studies reporting on the impact load experienced by dancers.

Table 2.9 Studies on impact load in dance.

Researcher/s (date)	Participants	Study design	Instrument	Conclusion
Boros and Skelton (2009)	6 female ballet dances (level: pre-professional, college dance students; age 19.7 ± 2.7yrs)	Five basic ballet skills in isolation and as part of a dance sequence, wearing ballet slippers.	- Force plate	Skills performed as part of a sequence produced higher impact forces (N/kg) compared to both isolated skills (grand plié, changement, entrecht, arabesque, cabriole) and locomotion (walk, jog, hop). Dance routine's peak impact force was at average 2.3 times body mass.
Chockley (2008)	7 female university-level ballet students (similar weight and height)	Two sets of three consecutive jumps starting and landing on 1)full foot and 2) en point.	- Force plate (under left foot)	Total GRF is the same when en point's lower jumping height was taken into account, but shock absorption time is half when landing en pointe and therefor increase injury risk in the lower extremities.
Kulig et al. (2011)	12 elite pre-professional dance students (6 male, 6 female) Various dance styles including ballet and modern.	Peak vGRF of a saute de chat landing.	- AMTI force platform - Eight-camera Vicon system	Landing force greater than walking, running, gymnastics split leap, landing from a 1.3 horizontal jump.
Liederbach et al. (2006)	Ballet and modern. University programs, advanced level studios	16 classes of each ballet and modern. Class duration 1.5 hours.	- Counted jumps from video recordings	Ballet classes displayed a 38% greater demand in total jumps (232), compared to modern classes (154). Ballet classes

	and professional companies.			displayed twice as many angular jumps (55) compared to linear jumps (24).
Orishimo et al. (2009)	Professional ballet and modern dancers. (12 male, age 25 ± 4yrs; 21 female, age 27 ± 5yrs)	Difference in jump landing kinematics and GRF between male and female dancers. Performed three single leg drop landings on dominant leg.	- 30cm high box - Force plate - Eagle cameras and 20 reflective markers.	No kinematic differences in male and female motion analysis or in peak vertical GRF (normalised to body weight). Peak GRF similar to recreational athletes. Landing phase duration was longer in dancers than athletes. Landing phase similar to gymnasts.
Picon et al. (2008)	6 female ballet dancers (age 17 ± 2.1yrs)	Influence of ballet shoe and musical beat on GRF during repetitive jumps. Two sets of eight consecutive sautes for four conditions; fast and slow beat each with slippers and pointe shoes.	- Force platform (vertical component GRF) - Music with specific pace	Music beat has a great influence on vertical GRF compared to ballet shoe type. More attention on landing technique is required when jumping on a faster beat due to shorter ground contact time.
Walter et al. (2011)	18 collegiate female ballet majors	GRF between double foot jump landing with ballet slippers vs pointe shoes. Six assemble jumps performed in each shoe.	- Force plate - Camera (height measurement)	No difference in jump height comparing shoe types. Pointe shoes significantly lower maximum GRF compared to slippers. Increased material layers in pointe shoes absorbs some GRF and disperse force away from the body.

Note: vGRF = vertical ground reaction force

Dancing in pointe shoes had no influence on jump landing peak vertical ground reaction force (vGRF) compared to dancing in ballet flats (slippers) when landing on a full foot (Picon et al., 2008). Even though landing on full pointe in pointe shoes showed the same peak vGRF as landing on a full foot when jump height was taken into account, the landing phase en pointe was almost half the time (Chockley, 2008). Consequently, the body had to absorb the landing shock in a shorter time when wearing pointe shoes which poses greated risk for injury (Chockley, 2008). When male and female dancers (modern dance and ballet) were compared to other athletes, they showed similar peak vGRF but a longer landing phase during single leg drop landings while wearing athletic shoes (Orishimo et al., 2009). It can thus be concluded that the years of balance and jump-landing technique training dancers receive from a young age (Orishimo et al., 2009) ensures that they distribute jump landing impact over an increased landing period.

Ballet dancers use a landing technique called ‘rolling through the foot’ which extend their ground contact time in between jumps (Chockley, 2008). Dancers are taught to point their toes (fully plantar flex their ankle) while in flight phase of a jump and use the full articulation of the foot during landing phase (rolling through the foot), this in combination with their increased plantar flexion range of motion (Chockley, 2008) and hip dominant landing strategy, all contribute to a longer landing phase and a jump landing pattern which lowers injury risk of lower extremities (Orishimo et al., 2009). In contrast to the beneficial prolonged landing phase and hip landing strategy used by dancers, Kulig et al. (2011) found that dancers have a decreased knee angular stiffness approach to jump landings compared to other athletes. The author stated that a decreased joint angular stiffness has been associated with an increased risk for soft tissue injuries.

Orishimo et al. (2009) compared recreational athletes’ jump landing vGRF to that of modern and ballet dancers’, by measuring a single legged landing from a specific height (30cm high box). Although no difference in peak vGRF was found between dancers and athletes, the study’s methodology leaves uncertainty regarding natural jump heights of the dancers compared to athletes in sport codes. Another factor that should be taken into consideration when comparing ballet dancers’ jump impact loads to sport codes is the sprung wooden flooring on which dancers train and perform. The more resilient the floor, the more force it can absorb (Fiolkowski & Bauer, 1997) and landing phase of jump it can increase. In contrast, team sports are performed on more rigid surfaces. Jump landings from dance routines had greater GRF than isolated ballet skills, walking, running and hopping (Kulig et al., 2011).

By using force plates and cameras for analysis constrain dancers to the spatial limitations of laboratory testing. An accelerometer could be used to record the total impact load of dancers without constraining them to a laboratory or a force plate. An accelerometer can monitor the impact load on three axes – vertical, horizontal right-left and horizontal front-back – and includes the vector magnitudes in each direction. For this reason, an accelerometer (as part of the STATSports® GPS, Ireland) was used in the current study.

Accelerometer

An accelerometer can be used as an alternative to a force plate as an indirect measure for determining the impacts an athlete experience. Excellent intra- and inter-accelerometer reliability has been reported by Kelly et al. (2015). Regarding validity, Kelly et al. (2015) reported that accelerometers underestimate acceleration by 32–35%, while Wundersitz et al. (2015) reported that raw data and 25–16Hz noise filters overestimate motion analysis peak acceleration. However, Wundersitz et al. (2015) concluded that accelerometers have an acceptable level of validity when a 12Hz noise cut-off filter is applied. The validity of computing vertical ground reaction forces with raw accelerometer data was supported by Pouliot-Laforte et al. (2014).

Only a few dance studies have made use of an accelerometer and only one has focused on the vertical impact load endured by dancers (Jeffries et al., 2017). In the study carried out by Jeffries et al. (2017) (previously discussed under sRPE monitoring method, section E), an accelerometer was used to record the vector magnitude, consisting of the summated vectors in all three axes. The vector magnitude describes the total stress experienced due to acceleration, deceleration and change of direction. An ActiGraph was worn around the waist on the non-dominant side of the body. Sampling was done at a rate of one second and at a frequency of 100Hz. The study found the average weekly vector magnitude load of all contemporary classes and rehearsals and ballet classes to be 1809.707 ± 1015.402 AU.

Twitchett et al., (2010) (previously discussed under training and performance demands, section B) documented the demands of a single working day for 51 professional female ballet dancers (corps de ballet N = 7; first artist N=16; soloist N=12; principal N=16). A device containing a two-axis accelerometer was used to calculate the energy expenditure in kilocalories and the exercise intensity in METS. The day was divided into periods of rest (<1.5 METS) and different training intensities (sedentary intensity (< 3 METS), moderate intensity (3–6 METS), vigorous intensity (6–9 METS)). Results showed a statistically significant difference between ranks of dancers for mean training intensity, the percentage of time spent at each training intensity and the time spent at rest. Of the dancers participating in the study, 90% also rested less than 60 minutes at any point in time and one-third rested for less than 20 minutes at any point in time.

Summary

When a monitoring method is chosen, it is important to consider the population, the cost effectiveness and sources available, how time-consuming the recording method is and how often it will be administered. All of these factors will affect compliance with the monitoring method. To monitor training load in the current study, the external training load was assessed using a GPS tracker. The internal TL was recorded by the use of sRPE method. To assess the recovery-stress state, the RESTQ-76 Sport questionnaire was implemented as a means of subjective physiological, psychological and sociological monitoring.

Chapter Three

METHODOLOGY

A. Introduction

This chapter includes a description of the study design, participants, testing procedures, measurements and instruments, ethical aspects, and statistical analysis used in the study. An explanation of the recruitment of participants, as well as the inclusion and exclusion criteria applied, follows the section on the study design. The testing procedures section includes the place of study, timeline, a description of the pilot study and the reporting system implemented. Following this, measurements and instruments used for evaluation of anthropometric measurements, recovery-stress states, and internal and external training load are discussed. Ethical aspects of the study are outlined in the penultimate section, followed by a description of the statistical analysis.

B. Study design

The study followed a descriptive quantitative research approach with longitudinal monitoring of professional ballet dancers over one season. A convenience sample was used to recruit ballet dancers from one professional ballet company due to the quantitative nature of the variables assessed. Convenience sampling was preferred to purposive sampling, which is used only for qualitative data (Etikan et al., 2016). Data was collected to determine the ballet dancers' workload, pain and recovery-stress state during the Rehearsal and Performance phases. A pilot study was conducted before the start of data collection for this study.

Professional ballet dancers were monitored during two separate eight-week phases for a total of 16 weeks. Phase 1 (P1) of the study was conducted during the Rehearsal Phase, at the start of the ballet year, during May and June. Phase 2 (P2) of the study was conducted in the Performance Phase, towards the end of the ballet year, from December to the first week of

February. The Rehearsal Phase consisted predominantly of technique classes and rehearsal. The Performance Phase encompassed technique classes, rehearsals, as well as performances.

C. Participants

Recruitment

The target study population was professional ballet dancers employed in a full-time capacity at a ballet company within the Republic of South Africa (RSA). There are only two professional classical ballet companies in the RSA. The researcher was based in Stellenbosch, near Cape Town and only the one company near by was conveniently selected to participate in this study due to logistical and budgetary constraints. A total of 35 individuals volunteered to participate in the study at the start of data collection. Eight individuals were excluded from the study at the start of Phase 1 as a result of not meeting the inclusion criteria.

In order to be included in the study a participant was required to be:

- a professional ballet dancer;
- older than 18 years of age;
- a full-time contracted dancer with the company; and
- able to communicate effectively in English.

Participants were excluded from the study if they had been discharged from all company training at the start of the study due to an injury. However, in the event that the participant was allowed to resume training with the company within one week of the start of the study, they were included after the commencement of training. In addition to this, dancers who suffered a major injury that prevented them from participating in any company training after the start of data collection were excluded. All data collected from such dancers until the time of injury was included in the study. To limit uncontrollable variables that might influence the outcomes of the study, the population was restricted to professional ballet dancers. These variables include, but are not limited to, a wide range in technique level (non-homogeneous group), number of training hours per week and participation in additional sport activities on a competitive basis.

The ballet company's acting executive director granted permission to approach the company's dancers to partake in the study under ethical considerations. After an information session during which the aim and the procedures of the study were conveyed, dancers were allowed to ask questions. Volunteers underwent a pre-participation screening to ensure their eligibility to participate in the study, which was carried out by means of the pre-participation questionnaire (Appendix B). Those who qualified gave written informed consent (Appendix C) to participate in the study.

Participants

A total of 27 professional classical ballet dancers (17 female; 10 male) of the company participated in the study. The dancers recruited for this study were of different ranks within the company.

Dancers were grouped into three main categories: professional dancers, post-graduate dancers and graduate dancers. Those falling into the professional and post-graduate categories were full-time dancers involved in all company training and performances. Dancers in both of these categories were included in the current study. Professional dancers could be further grouped into three ranks, according to their level of performance within the company. These levels were: principal, soloist and artist. Post-graduate dancers are essentially at a level of performance of the artist rank in the company and were therefore accepted as professional ballet dancers for the current study.

Post-graduate dancers were those dancers who have completed a one-year graduate programme at the company. At the end of this programme, graduates would have been evaluated to determine whether they should be invited to stay on with the company. Dancers who receive the invitation to stay with the company become post-graduates who train and perform with the company on a full-time basis, but who do not yet have professional dance contracts with the company. Graduates were not included in the study.

Figure 3.1 offers a description of the three main groups of dancers at the company (professional [principals, soloists, artists], post-graduate and graduate dancers), and what groups were included in the study (groups one and two).

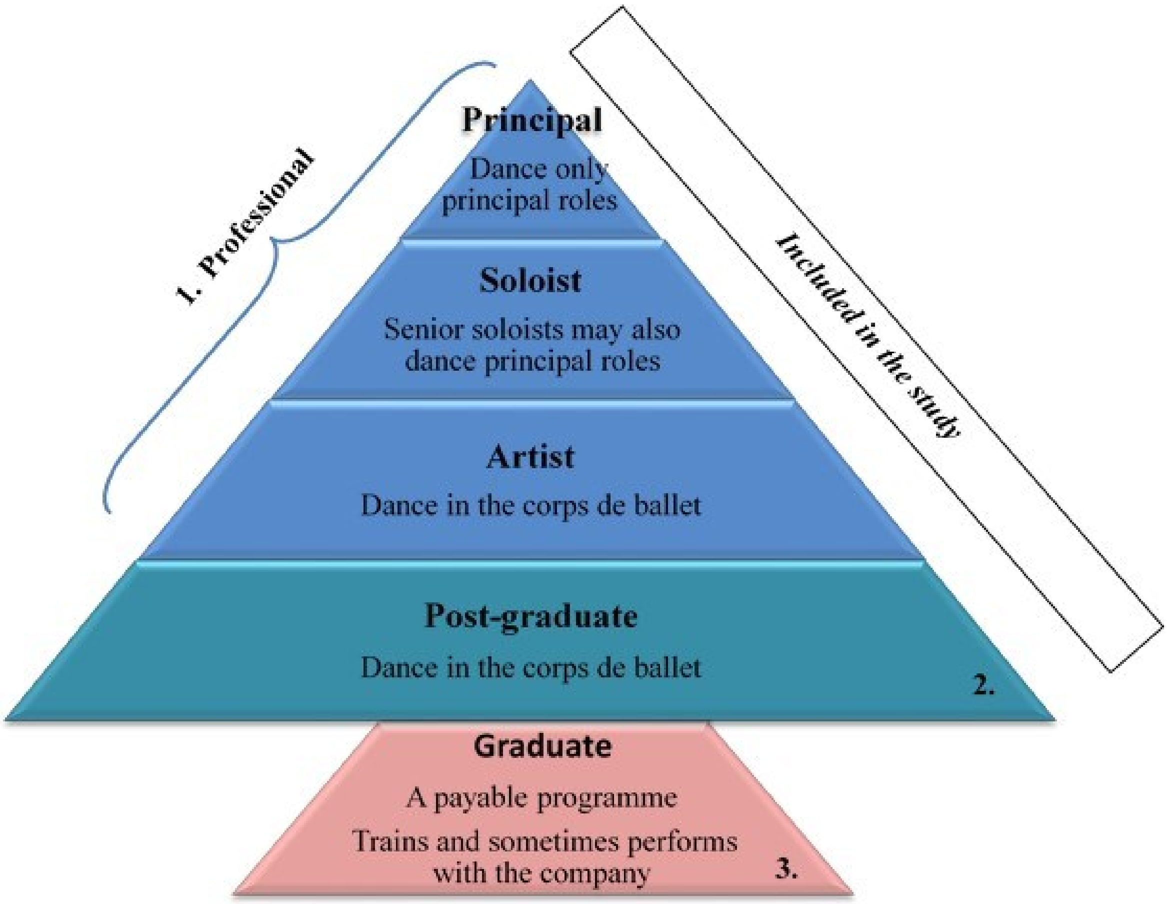


Figure 3.1 **The three main groups of dancers involved in training and performance at the company, the levels considered for inclusion in the study and the ranks within the professional group of dancers.**

Participants were grouped into two levels of performance: higher-level and lower-level dancers. Post-graduates and artists were grouped together as PGA (lower-level), while soloist and principal dancers were grouped together as SP (higher-level). Grouping was done a) due to the low number of dancers in each level of performance and b) because certain roles were performed by dancers from different levels of performance; for example, the senior soloist also danced in principal roles.

An initial group of 20 dancers was involved in Global Positioning System (GPS) data collection. The number of dancers was limited by the number of GPS sets available to the researcher. The distribution of dancers selected is shown in Table 3.1. Within each rank, the participants who were most consistent in completing the online reports for pain and training load during the first week were selected. An equal number of male and female participants were selected.

Table 3.1 Initial GPS participants.

Level	Sex	Number
Principal	Female	n = 1
	Male	n = 1
Soloist	Female	n = 5
	Male	n = 5
Artist	Female	n = 4
	Male	n = 4

D. Testing procedures

Different variables were monitored at daily, weekly and monthly intervals. Anthropometric measurements were taken in the first week of P1 and P2, and again in the final week of P2. Participants reported their pain level (Table 3.7) and the location of the pain (Figure 3.3) on a modified Self-Estimated Functional Inability because of Pain (SEFIP) questionnaire daily (Appendix D). All company dance-related training, as well as any additional training, were reported daily (Appendix E). Participants were also asked to complete the Recovery-Stress Questionnaire for Athletes once per week, before or directly after their first ballet class of the day. During P1, a group of participants representative of both male and female dancers in all three ranks wore a STATSports Vipre® GPS unit (Ireland) during company training. The screening and testing procedures are shown in Figure 3.2 below.

Place of study

Participants were evaluated at the Rondebosch Sport and Recreation Club, where the company trains, during P1 and part of P2. Most of the weekly testing during P2 was carried out at the Artscape Theatre Centre, where the company performs.

Timeline

The testing period was determined by the ballet company's pre-planned performance and rehearsal schedule for the year. Eight weeks was set aside for both P1 and P2. Data collection took place between May 2018 and February 2019.

Pilot study

A pilot study was conducted after ethical clearance was granted. Three elite ballet students performed the same procedures, as described below, on one day. The reason for the pilot study was to assist with accurate time management, as well as to allow the researcher to become familiar with the STATSports Vipre® GPS system (Ireland). Students for the pilot study were recruited by contacting ballet schools in the Stellenbosch area. The first ballet school that gave consent to approach its dancers was used for the pilot study. Participants from only one ballet school were included for practical reasons. One female dancer was below the age of 18 years. In addition to the participant herself, the parent of the minor participant was required to sign a consent form.

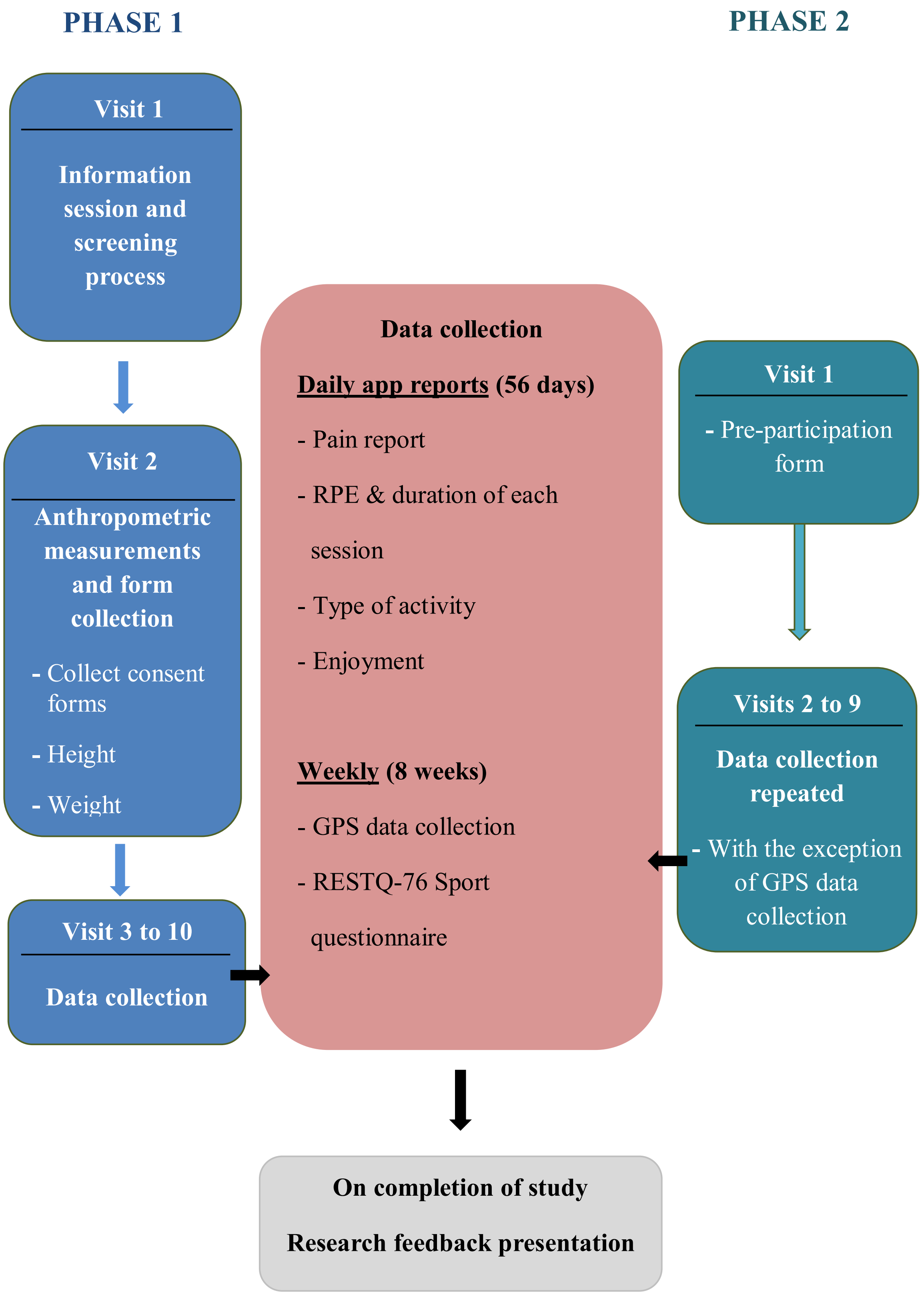


Figure 3.2 Flow diagram of screening and test procedures of the two phases of data collection.

Reporting system

In order to simplify the daily reporting process and improve compliance, reports on pain, non-dance activities and internal training load were submitted by means of AthleteMonitoring (Canada), an online application that was downloaded onto each participant's mobile phone. This also enabled participants to complete the daily reports over weekends and after performances.

A WhatsApp® group was used to convey additional information as well as to send out reminders to the participants. Participants received a daily reporting reminder via email towards the end of the working day. Additionally, a reminder on the WhatsApp® group was sent if more than ten participants had not submitted their report. In the case where fewer than ten participants' reports were outstanding, a personal reminder message was sent on WhatsApp® to the specific participants.

E. Measurements and instruments

The SEFIP questionnaire is available in the public domain. The recovery-stress questionnaire (RESTQ-76 Sport) was available from purchasing the Recovery-Stress Questionnaire for Athletes: User manual (Kellmann & Kallus, 2016). Administering the questionnaire did not require a psychometric qualification, therefore all questionnaires were administered by the researcher. The questionnaires were not used to diagnose the dancers, but for descriptive and monitoring purposes.

Anthropometric measurements

All anthropometric measurements were carried out by a qualified ISAK level 1 registered biokineticist (BK0025690).

Standing height (stature)

A sliding steel stadiometer (DKSH, Switzerland) was used to measure the standing height of each participant to the nearest 0.1 centimetre (cm). Measurements were taken once during the first week of the study in the morning, either before or after the first ballet class, using the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK, 2001). As the Frankfort horizontal plane method was used, the plane from the lowest point of the eye socket (orbital) was aligned to the highest point of the ear canal (tragion) and positioned horizontal to the floor. Participants were measured barefoot, as specified by the ISAK guidelines.

Body mass

An electronic scale (Body Composition Monitor, Japan) was used to measure each participant's body mass (BM) in kilograms (kg) to the nearest 0.1 kg. The scale was calibrated before each use. Participants were wearing minimal dance clothing and were barefoot or wore ballet slippers. Ballet slippers are light in weight, flexible and constructed from either soft leather or canvas (Walter et al., 2011).

Each participant's weight was measured at the beginning of P1, as well as at the beginning and the end of P2. Weight was recorded in the morning. Participants who were part of the GPS-testing group, had an additional weight measurement taken half way through P1 (at the start of week 5). This was done to ensure accuracy of the GPS data collected during P1.

Recovery-stress states

The RESTQ-76 Sport (Kellmann & Kallus, 2001) was used to monitor each dancer's recovery-stress state on a weekly basis throughout both phases. Once per calendar week, with at least three intervening days, each dancer completed the questionnaire before or shortly after the first ballet class of the day. RESTQ-76 Sport scale definitions are provided in Appendix A.

Training load

Training load (TL) was measured using two different methods, namely: internal training load (sRPE) and external training load (impacts).

Internal training load

Subjective internal training load (sRPE-TL) was recorded with the Session-RPE method, including session-RPE intensity score and the duration of the session. According to the guidelines from research mentioned previously, each participant was required to report their Session-RPE rating no sooner than 30 minutes and no later than 24 hours after each training session. The extended reporting time was for practical reasons, due to sessions frequently following each other without an intervening 30-minute break. Reporting could thus not always be done after each individual session. Dancers reported the appropriate athletic hours for each session accurately to five minute fragments. Sessions were created on the AthleteMonitoring (Canada) application according to the ballet company schedule and dancers could reject scheduled sessions and add new sessions as needed (Appendix E). Each training session was recorded on the application based on type (Appendix E). This was done to distinguish between ballet training (technique class, rehearsal, performance) and non-dance activities (additional or individual training). Prior to the start of data collection, each participant was thoroughly informed about the rating system.

The modified version of the RPE scale (Foster et al., 2001) used in P1 differed slightly from the one used in P2. This was due to changes made by AthleteMonitoring (Canada) on their online system in the period between the two data collection phases. The two scales are shown in Table 3.2 below. Changes are indicated in bold italic font. Changes included removal of one ‘easy’ anchor word and the addition of one ‘hard’ anchor word. The change was handled with great care and participants were made aware of the change in the scale. Phase 1 data were remapped to the new RPE descriptors with the assistance of the AthleteMonitoring (Canada) team to ensure that the data of both phases matched the new descriptors.

Table 3.2 Modified Rate of Perceived Exertion scale of AthleteMonitoring (Canada) used in Phase 1 and Phase 2.

How hard was it?		
Perceived exertion	**Description (Phase 1)**	**Description (Phase 2)**
0	Rest	Rest
1	Very, very light	**Very, very easy**
2	Very light	**Easy**
3	Fairly light	Moderate
4	Moderate	Somewhat hard
5	Somewhat hard	Hard
6	Hard	**Truly hard**
7	Very hard	Very hard
8	Very, very hard	Very, very hard
9	Extremely hard	Extremely hard
10	Maximal	Maximal

External training load

GPS system (STATSports Viper®, Ireland) was used to objectively quantify the external training load of dancers at various levels. The model used in the current study is the STATSports viper® version 1.2, 2012 (Canada). This GPS collects data at a frequency of 10Hz, tri-axial accelerometer at 100Hz, magnetometer at 10Hz, gyroscope at 100Hz. The metric investigated was vertical impact, as described in Table 3.3.

Impacts were categorised into standard STATSports® (Ireland) zones of magnitude to investigate the number of impacts in each zone (Table 3.4).

Table 3.3 STATSports Viper® Metric Descriptions (Ireland).

METRIC	SUMMARY
Impacts	The 100hz 3D accelerometer continually records the magnitude of accelerometer values above 2G in a 0.1 second period. Impacts are divided into six zones according to the magnitude (Table 3.4).
Vertical impact	Total summated impact magnitude for the entire session recorded.

Table 3.4 STATSports® GPS Zones (Ireland).

GPS Zones	
Zone	**Impact (G-force)**
1	3–4.99
2	5–6.99
3	7–8.99
4	9–10.99
5	11–12.99
6	13–15

Participants were fitted with a GPS system once per week during P1 before the day's training started. This was done on a Wednesday, as far as practically possible. The system was calibrated before each use. The pods were numbered and a specific number was allocated to each participant for the duration of the study.

In the case of injury or absence of one of the GPS-group participants, another participant was randomly selected to train with that GPS for the day to ensure that data points were not lost. This was possible since the data was collected to compare the subjective and objective training load of sessions and TL of dancers at a specific level, instead of testing a specific dancer.

All systems were switched on at the start of each training session. The GPSs was switched off during rest periods that was longer than 30 minutes. At the end of each day's training sessions, the systems were switched off and collected. Notes were made on the time periods for which dancers were in class and rehearsals. These times were used to determine what data to extract from STATSports® (Ireland) devices to analyse for the study. One day per week, the RPE-TL and the GPS-TL were both recorded for each ballet session to compare the two training load measures (internal and external).

Perceived pain

The SEFIP questionnaire is specifically designed to document dancers' level and location of pain. The terms used to describe the pain level and the pain/coping mechanism are specific to dancers (Ramel et al., 1999). The SEFIP questionnaire was developed by Ramel et al. (1997). Ramel et al. (1999) found that it had a mean sensitivity of 78% and specificity of 89% for dancers.

An adapted version (Table 3.5) of the SEFIP questionnaire was used to document each participant's musculoskeletal pain during the rehearsal and performance phases. One suitable pain descriptor was chosen by each participant to describe their holistic feeling at that particular moment instead of describing each individual body region. The location(s) where pain was felt was then reported simply by listing the anatomical regions, using the anatomical diagram in the SEFIP instrument designed by Ramel (1991) (Figure 3.3). The diagram could not be placed on the mobile application where reporting took place, but was presented on the information board in the company's training studio and was sent to the participants via WhatsApp®.

Each participant completed the adapted SEFIP questionnaire, answering the question "How do you feel just now? (regarding musculoskeletal pain)" daily. Descriptors were translated to numbers for analysis purposes, with no pain ("Very well") as 0 and maximum pain ("Can not work in the production because of pain") as 4, as described by Ramel et al. (1999) (Table 3.5). Dancers were instructed to answer the question after the day's ballet training, but no earlier than 18:00 on both working (ballet training) and off (rest) days. This time was decided upon after considering the average end time of daily training during P1.

Table 3.5 Adapted version of the Self-Estimated Functional Inability because of Pain scale (Ramel et al., 1999).

How do you feel just now? (regarding musculoskeletal pain)	
0	Very well
1	Some pain but not much
2	Pretty much pain but I can handle it
3	Much pain, must avoid some movements
4	Can not work in the production because of pain

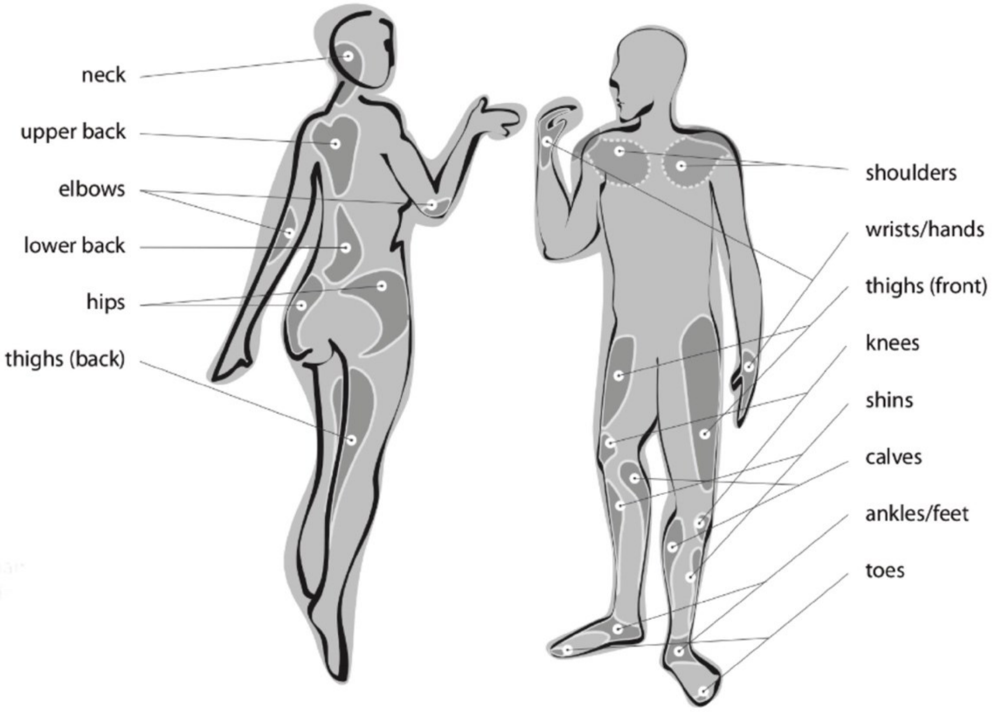


Figure 3.3 **Anatomical pain sight of the Self-Estimated Functional Inability because of Pain questionnaire (Ramel, 1999).**

F. Ethical aspects

The study proposal was approved by the Research Ethics Committee (REC) at Stellenbosch University (REC-2018-7023). At the first meeting with the interested participants, the study was explained verbally. If potential participants decided to volunteer for the study, they were given the pre-participation and informed consent forms to read through and complete in their own time. At the follow-up meeting, the pre-participation and signed informed consent forms were collected. A copy of the informed consent form was emailed to each participant.

Participation was voluntary throughout the study and participants could withdraw at any point without any consequences. All data obtained during the course of the project have been handled with strict confidentiality and kept at the Department of Sport Science, Stellenbosch University, which is access controlled and equipped with an alarm system. All hard copies have been stored in a safe at the Department of Sport Science at Stellenbosch University and will be kept for six years, after which they will be destroyed. All data were stored on a password-protected computer or external hard drive and are only accessible by the primary investigator. Copies of the data are also stored on an external hard drive and located in the supervisor's locked office.

Each participant was able to see only his or her own online application data (AthleteMonitoring, Canada). The collected data were only accessed by the researcher, the study supervisors and the statistician. Confidentiality was enhanced by a coding system (e.g. Jana de Wet was labelled CTCB01). At the end of the research study, participants were invited to a feedback session where the primary outcomes of the study were shared. The primary investigator, who collected the data and interacted with the participants, has at all times conducted herself in a professional manner and in accordance with the Declaration of Helsinki. She is a registered biokineticist with the Health Professionals Council of South Africa (BK0025690).

The procedures and activities used in this research project posed no serious risks to the participants. No harm was done to the well-being of the participants and no invasive procedures were included in the study. The GPS harness had the possibility of being slightly uncomfortable, but various sizes were available to ensure the best fit for each participant.

G. Statistical Analysis

One-way analysis of variance (ANOVA) was used to compare demographic variables between groups. For comparisons of measurements taken over weeks and between phases, a mixed-model ANOVA was used. Participants were treated as random effect, while group, phase, week and activity were treated as fixed effects. For post hoc testing, Fisher's Least Significant Difference (LSD) was used. The one-way ANOVA's were carried out using TIBCO Statistica 13.5.0, and the R package "lmer" was used for the mixed models.

Correlations analyses were conducted using Pearson and Spearman correlations, calculated in TIBCO Statistica 13.5.0. Due to repeated measurements on the participants and possible transgressions of the assumption of independent observations, repeated measures correlations were also calculated using the R “rmcorr” package (Bakdash & Marusich, 2017). In general, the correlations were found to be similar and the Pearson correlations were reported in most cases.

Comparisons between sexes and between levels of performance (levels) are of phase averages. In some instances, averages for the different weeks are reported to show weekly fluctuations and to report on the difference between the beginning (week 1) and the end point (week 8) of the specific phase. Weekly fluctuations are determined by comparing the weekly averages of two consecutive weeks. If the difference in averages was statistically significant, a significant fluctuation was reported. Where significant values were found, sex-specific levels were also compared over the two phases. A change or difference is statistically significant when $p \leq 5$, and will be referred to only as a significant change or difference. Strength of correlations were evaluated according to Cohen’s guidelines (Cohen, 1998). r: weak (<0.3), moderate (≥0.3 and <0.5), strong (≥0.5 and <1).

Chapter Four

RESULTS

A. Introduction

This chapter presents the results of the current study, based on the aims of the study. For each variable, the results are presented in the following order: First, the results of Rehearsal Phase (P1) are discussed, including the results of total group, sexes (male and female dancers) and levels of performance (levels) (soloist-principal and post graduate-artist groups). Second, the results of the total group, sexes and levels in Performance Phase (P2) are discussed. Finally, a comparative examination of P1 and P2 is carried out.

B. Participants

The baseline descriptive characteristics of the participants for P1 and P2 respectively are shown in Table 4.1. No new participants were added to the study after the start of P1. However, some participants were excluded from P2 due to the reasons specified in Figure 4.1 and Figure 4.2, presented on the next page.

Table 4.1 Phase 1 and Phase 2 baseline demographics (mean ± SD) for all participants.

	Phase 1		Phase 2	
Characteristics	**Male**	**Female**	**Male**	**Female**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Participants (N)	**10**	**17**	**9**	**14**
- Principal	1	1	1	1
- Soloist	5	8	4	8
- Artist	4	5	4	3
- Post graduate	0	3	0	2
Height (cm)	177.9 ± 9.2*	166.2 ± 4.2*	-	-
Body mass (kg) **- pre**	76.2 ± 13.0*	56.5 ± 5.2*	75.6 ± 14.5*	55.3 ± 4.8*
- post	-	-	75.8 ± 13.7*	55.3 ± 4.8*
Age (years)	28 ± 6.0	25 ± 4.2	27 ± 5.3	25 ± 4.4
Professional ballet career (years)	9 ± 6.4	5 ± 4.5	-	-

*p≤0.01 significant difference between males and females

There was no significant change in body mass for either male or female dancers between the two phases (male p=0.59; female p=0.89), or between the start and end points of P2 (male p=0.90; female p=0.51). Male dancers weighed significantly more (p<0.01) and were significantly taller (p<0.01) than female dancers throughout the year. A clear trend towards a significant difference was seen in the amount of years each sex group has been dancing professionally (p=0.06).

Figure 4.1 and Figure 4.2 describe the participation of dancers throughout the study. These figures depict the changes in participants involved in the various subjective reporting methods.

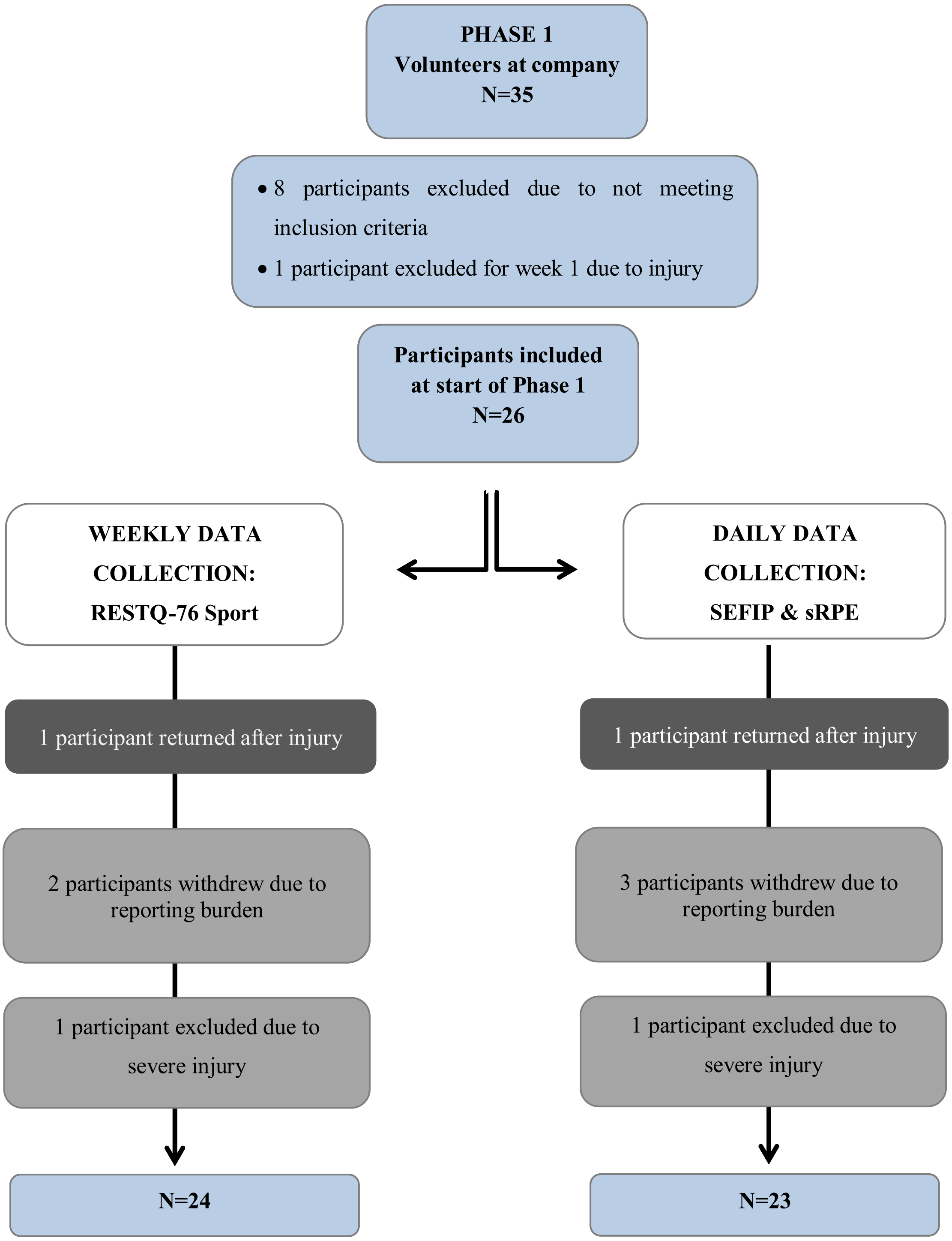


Figure 4.1 **A flow diagram showing participation of dancers in all subjective variables during Phase 1.**

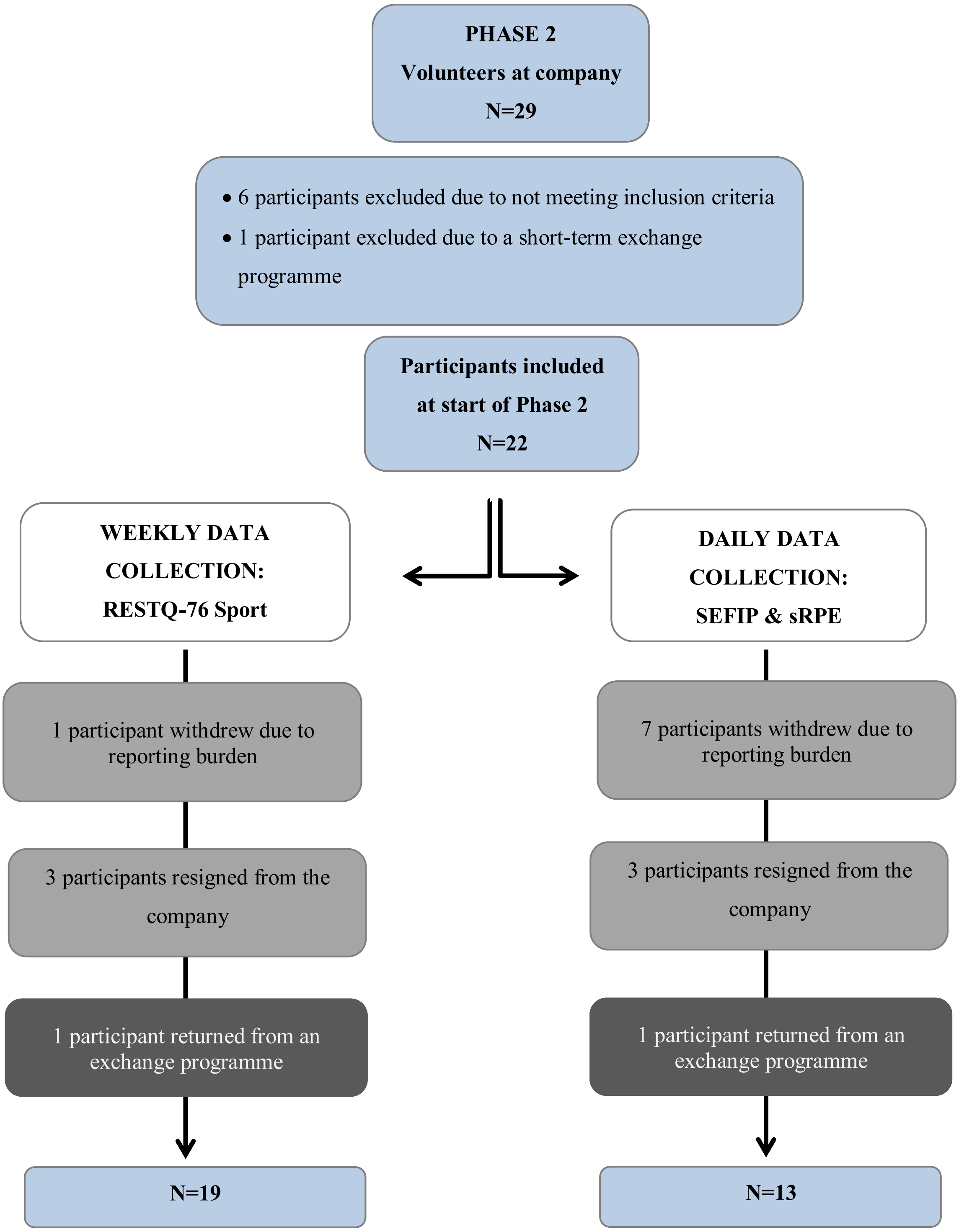


Figure 4.2 A flow diagram showing participation of dancers in all subjective variables during Phase 2.

The number of data sets collected in P1 and P2 for all data collection methods are shown in Table 4.2. Further to this, Table 4.2 indicates the number of stage performances per week as well as the number of days the total group was not required to participate in company activities (training, stage performance and other company-related activities). A total column on the right indicates the total number of performances, off days and data sets for each phase.

Table 4.2 Company off days and performance schedule for Phase 1 and Phase 2, including the number of data sets per week for each variable.

	Phase 1								
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Performances	0	0	0	1	0	3	0	3	7
Days off	2	2	2	2	2	1	2	2	15
SEFIP	140	146	154	149	145	124	108	90	1056
sRPE TL	116	114	118	134	118	131	80	110	921
RESTQ-76 Sport	21	24	22	23	24	24	23	22	183
GPS units	12	13	15	16	16	14	14	16	116

	Phase 2								
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Performances	5	5	5	6	0	0	4	1	26
Days off	0	1	3	2	3	5	0	4	18
SEFIP	81	74	64	71	75	62	49	62	538
sRPE TL	118	106	90	114	45	23	107	36	639
RESTQ-76 Sport	20	19	13	18	17	17	17	17	138

Note: SEFIP = Self-Estimated Functional Inability because of Pain, sRPE TL = session RPE training load, RESTQ-76 Sport = Recovery-Stress Questionnaire for Athletes

C. Recovery-stress states

The results of all the RESTQ-76 Sport (RESTQ) scales, as well as the significant differences between P1 and P2 for total group, male dancers, female dancers and levels can be seen in Table 4.3. Figure 4.3 shows the average scores of all subscales for male and female dancers respectively for P1 and P2.

Table 4.3 RESTQ-76 Sport scores of all scales and subscales for the total group of dancers (All), male dancers, female dancers, as well as soloist-principal (SP) group and postgraduate-artist (PGA) group.

		Phase 1					Phase 2				
		All	**Male**	**Female**	**SP**	**PGA**	**All**	**Male**	**Female**	**SP**	**PGA**
	Total stress	1.83± 0.82	1.82± 0.91	1.84± 0.78	1.72± 0.81	1.99± 0.81	2.46± 0.93	2.51± 0.92	2.43± 0.95	2.45± 0.91	2.48± 0.99
	Total recovery	3.04± 0.78	3.27± 0.79	2.95± 0.76	3.08± 0.67	2.99± 0.91	2.75± 0.79	3.19± 0.77*	2.50± 0.68*	2.73± 0.74	2.81± 0.89
General	**General stress**	1.90± 0.84	1.85± 0.86	1.93± 0.84	1.74± 0.76	2.12± 0.90	2.34± 0.88	2.27± 0.87	2.38± 0.89	2.37± 0.84	2.29± 0.98
	General recovery	3.14± 0.87	3.25± 0.98	3.09± 0.82	3.19± 0.79	3.07± 0.96	2.79± 0.84	3.11± 0.91*	2.60± 0.74*	2.75± 0.79	2.87± 0.95
Sport-specific	**Sport-specific stress**	1.77± 0.91	1.86± 1.09	1.73± 0.82	1.72± 0.96	1.83± 0.83	2.61± 1.14	2.77± 1.12	2.51± 1.14	2.58± 1.13	2.66± 1.16
	Sport-specific recovery	2.94± 0.85	3.21± 0.82	2.83± 0.84	2.96± 0.76	2.91± 0.96	2.73± 0.85	3.29± 0.77*	2.40± 0.71*	2.72± 0.82	2.74± 0.91
General stress	**General stress^**	1.47± 1.23	1.32± 1.21	1.53± 1.24	1.24± 1.04	1.78± 1.40	2.03± 1.36	1.97± 1.40	2.07± 1.34	2.01± 1.28	2.08± 1.52
	Emotional stress	1.67± 1.00	1.48± 1.05	1.76± 0.96	1.61± 0.91	1.75± 1.11	2.13± 1.14	1.94± 1.14	2.24± 1.14	2.21± 1.08	1.98± 1.27
	Social stress	1.55± 0.99	1.43± 1.05	1.61± 0.96	1.55± 0.91	1.56± 1.10	1.98± 1.13	1.72± 1.12	2.13± 1.11	2.05± 1.00	1.84± 1.36
	Conflict/ Pressure	2.70± 1.13	2.77± 1.32	2.67± 1.03	2.59± 1.26	2.86± 0.91	3.04± 1.02	3.10± 1.17	3.01± 0.93	3.08± 1.03	2.95± 1.00

General stress	**Fatigue**	2.26± 1.18	2.57± 1.14	2.12± 1.18	2.07± 1.10	2.53± 1.24	2.91± 1.24	3.33± 1.27	2.67± 1.16	2.89± 1.22	2.97± 1.29
	Lack of energy	1.85± 0.95	1.68± 0.94	1.92± 0.95	1.60± 0.76	2.18± 1.07	2.03± 0.90	1.76± 0.67	2.18± 0.97	2.02± 0.71	2.03± 1.21
	Physical complaints	1.83± 0.85	1.92± 0.83	1.79± 0.86	1.65± 0.76	2.08± 0.91	2.37± 0.91	2.39± 0.95	2.36± 0.90	2.38± 0.88	2.36± 0.99
General recovery	**Success**	2.98± 0.87	3.17± 0.95	2.89± 0.82	2.99± 0.91	2.97± 0.82	2.77± 0.97	3.20± 1.07*	2.53± 0.82*	2.70± 1.02	2.93± 0.85
	Social recovery	3.51± 1.22	3.25± 1.53	3.63± 1.04	3.47± 1.16	3.57± 1.31	3.14± 1.21	3.32± 1.51	3.03± 0.99	3.09± 1.15	3.24± 1.35
	Physical recovery	2.71± 0.92	2.86± 1.06	2.64± 0.84	2.75± 0.77	2.66± 1.09	2.35± 0.93	2.77± 1.13*	2.10± 0.69*	2.26± 0.86	2.54± 1.04
	General well-being	3.26± 1.10	3.33± 1.16	3.23± 1.08	3.32± 1.04	3.18± 1.19	3.01± 1.12	3.39± 1.25*	2.78± 0.97*	2.85± 0.97	3.34± 1.33
	Sleep quality	3.17± 1.19	3.40± 1.15	3.07± 1.19	3.33± 1.02	2.95± 1.36	2.74± 1.07	3.02± 1.00	2.58± 1.09	2.88± 0.84	2.45± 1.42
Sport-specific stress	**Disturbed breaks**	1.06± 0.83	1.05± 0.92	1.06± 0.79	1.06± 0.89	1.06± 0.76	1.88± 1.29	2.16± 1.29	1.71± 1.27	1.89± 1.21	1.84± 1.45
	Emotional exhaustion	1.76± 1.41	1.90± 1.54	1.70± 1.35	1.72± 1.37	1.81± 1.46	2.74± 1.53	2.71± 1.42	2.76± 1.60	2.62± 1.42	3.01± 1.72
	Injury	2.51± 1.09	2.68± 1.24	2.43± 1.02	2.40± 1.07	2.66± 1.12	3.22± 1.35	3.47± 1.37	2.68± 1.24	3.25± 1.26	3.15± 1.53
Sport-specific recovery	**Being in shape**	2.73± 1.04	3.00± 1.04	2.61± 1.02	2.84± 0.86	2.58± 1.23	2.32± 1.04	2.93± 1.06*	1.95± 0.84*	2.31± 0.98	2.33± 1.17
	Personal accomplishment	3.00± 0.97	3.09± 1.09	2.96± 0.91	3.03± 0.85	2.96± 1.12	2.75± 0.99	3.01± 0.94	2.59± 0.99	2.81± 0.88	2.61± 1.19
	Self-efficacy	2.61± 0.90	2.98± 1.00	2.46± 0.82	2.65± 0.85	2.57± 0.98	2.56± 1.06	3.26± 1.02*	2.16± 0.85*	2.58± 1.07	2.53± 1.04
	Self-regulation	3.45± 1.27	3.80± 1.14	3.29± 1.30	3.40± 1.28	3.52± 1.27	3.34± 1.29	4.09± 1.20*	2.90± 1.14*	3.26± 1.25	3.51± 1.38

Note: Where p≤0.05 between phases, orange depicts a significant increase from P1 to P2, green depicts a significant decrease from P1 to P2. * depicts a significant difference between either sexes or level of performance during the particular phase. General stress^ is a subscale of the main general stress scale and is therefore distinguished with a "^".

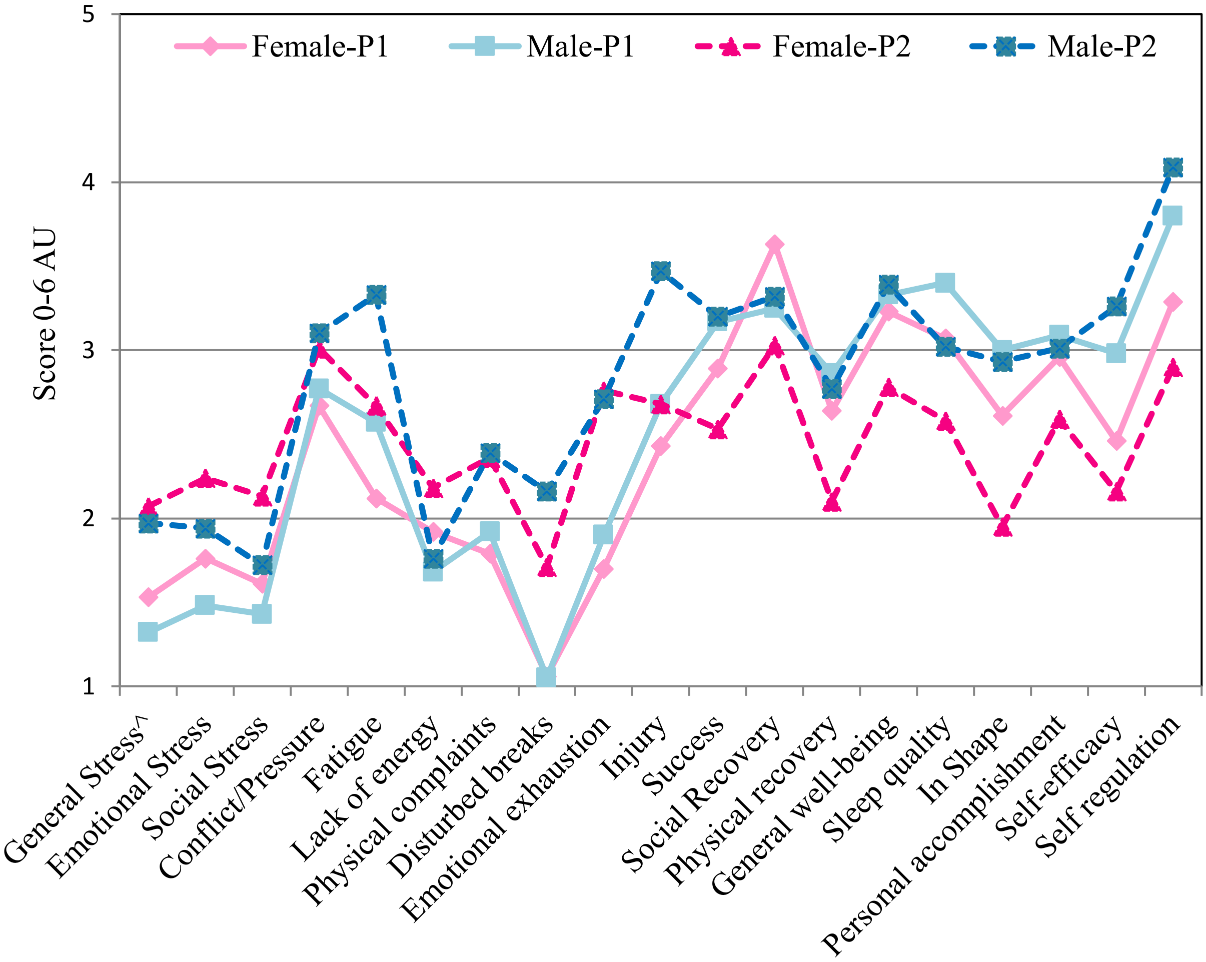


Figure 4.3 RESTQ-76 Sport average scores of all subscales for male and female dancers respectively for Phase 1 and Phase2.

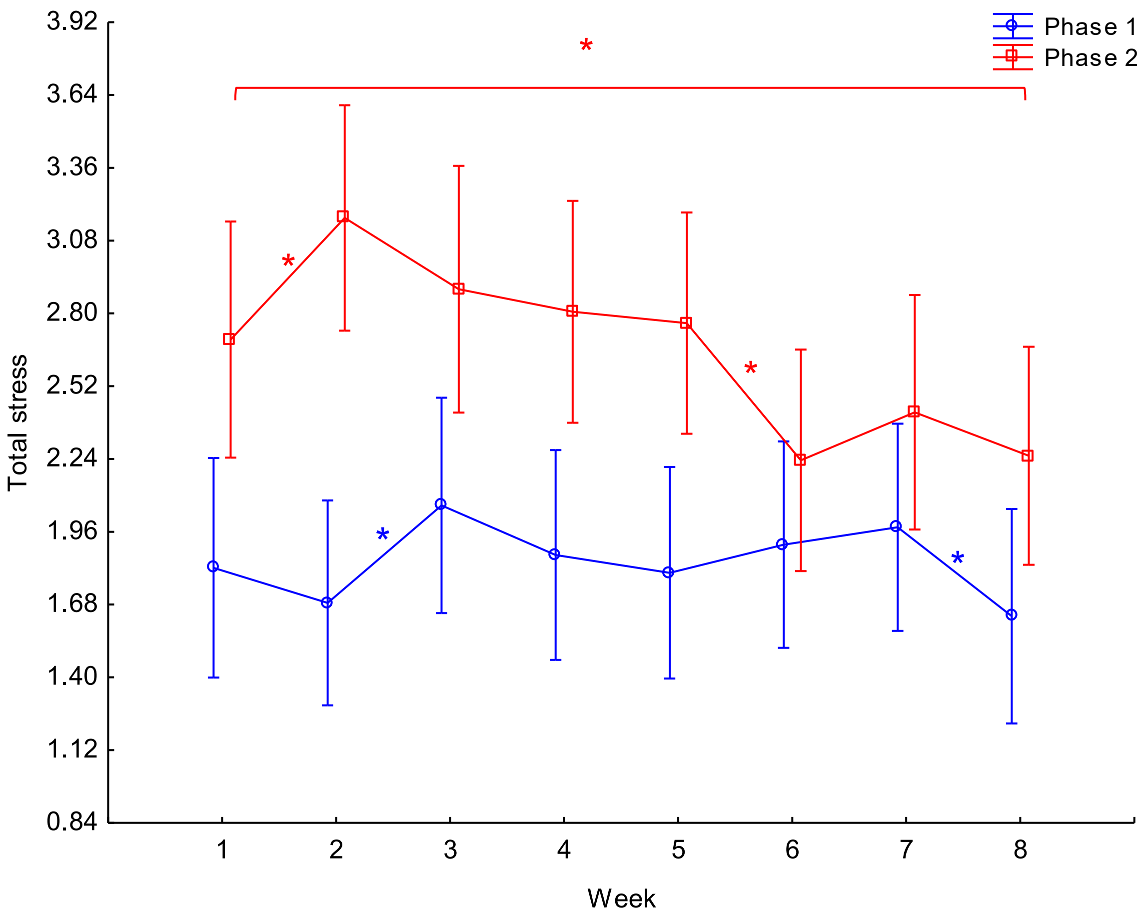
Total stress (TS)

Phase 1

For the total group, the weekly average total stress (TS) was not significantly different between the beginning (week 1) and end (week 8) point of P1 (p=0.23). However, significant fluctuations were noted between some weeks in P1. The total group had significantly higher TS scores in week 3 (p=0.01) compared to week 2, and lower TS scores in week 8 compared to week 7 (p=0.01) (Figure 4.4). There were no significant differences in TS between the sex groups (p=0.95) or the levels (p=0.26) for P1.

Phase 2

The total group had significantly lower TS in week 8 than in week 1 (p=0.01). After an initial increase in TS in week 2 (p=0.01), the weekly averages predominantly followed a downward trend, with significantly less TS in week 6 (p<0.01) compared to week 5 (Figure 4.4). Again, no significant differences in TS were seen between the two sex groups (p=0.95) or between the two levels (p=0.29) during P2.



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.4 Total stress of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The total group had significantly higher TS scores during P2 than during P1 (p<0.01). The weekly results were significantly different for the two phases (p<0.01). Figure 4.4 shows the differences for the total group between the two phases. Both sex groups ($p<0.01$) and levels ($p<0.01$) showed significantly higher TS scores during P2, with no significant differences between the sex groups ($p=0.85$) or levels ($p=0.92$)

Total recovery (TR)

Phase 1

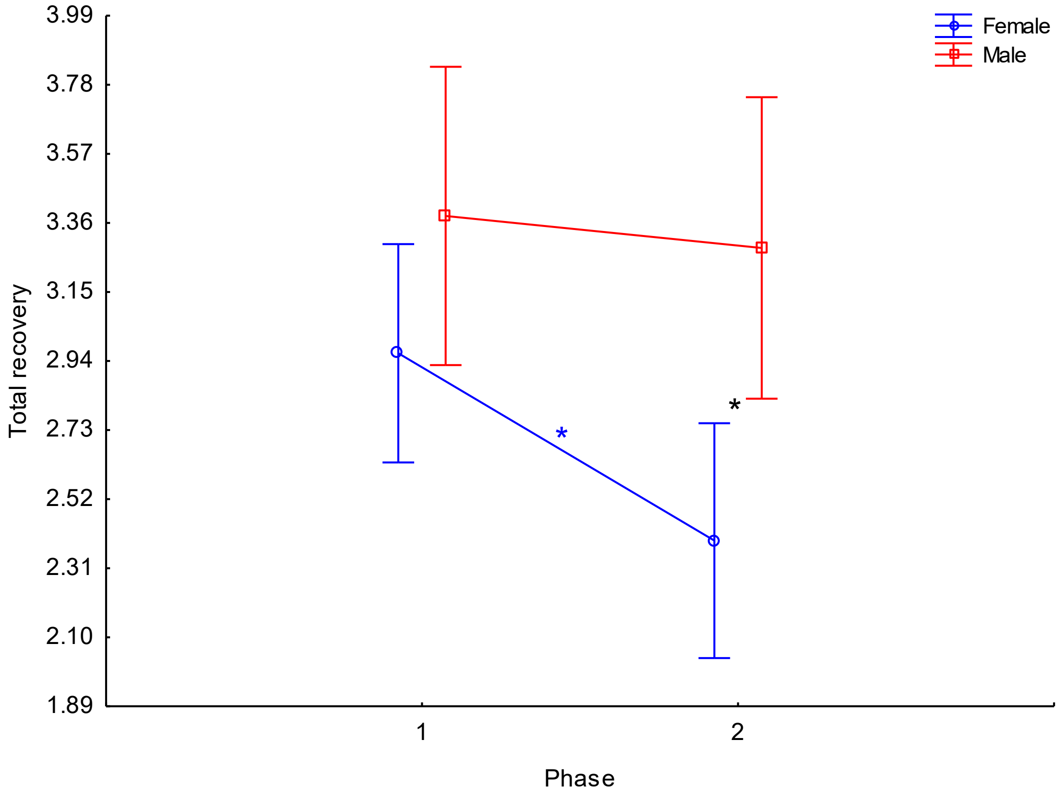
The total group's total recovery (TR) in P1, showed no significant difference in the weekly average between week 1 and week 8 ($p=0.43$). One significant decrease in the total group's TR was noted from week 2 to week 3 ($p=0.05$). No significant difference in TR was found between either the sex groups ($p=0.14$) or the levels ($p=0.69$) for P1.

Phase 2

The increase of the total group from week 1 to week 8 of P2 was not significant ($p=0.14$). After an initial decrease in week 2, the TR of the total group followed an upward trend. A decrease in week 5 ($p=0.07$) was immediately followed by an increase in week 6 ($p=0.08$). During P2, male dancers had significantly better TR compared to female dancers ($p<0.01$), however no significant differences were seen between the levels ($p=0.54$).

Comparison between Phase 1 and Phase 2

The total group showed significantly less TR in P2 compared to P1 ($p<0.01$). The weekly results of the two phases differed significantly from each other ($p=0.03$). A significant difference in phase averages between sex groups was observed ($p<0.01$). Male dancers showed no significant difference in TR between P1 and P2 ($p=0.46$). Female dancers, however, had significantly lower TR scores in P2 than in P1 ($p<0.01$). The differences between sex groups are shown in Figure 4.4 below. The SP group had no significant change ($p=0.07$) in phase average, whereas the TR phase average of the PGA group was significantly lower in P2 than in P1 ($p<0.01$). Levels did not differ significantly from each other over P1 and P2 ($p=0.12$).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.5 Total recovery of male and female dancers during Phase 1 and Phase 2.

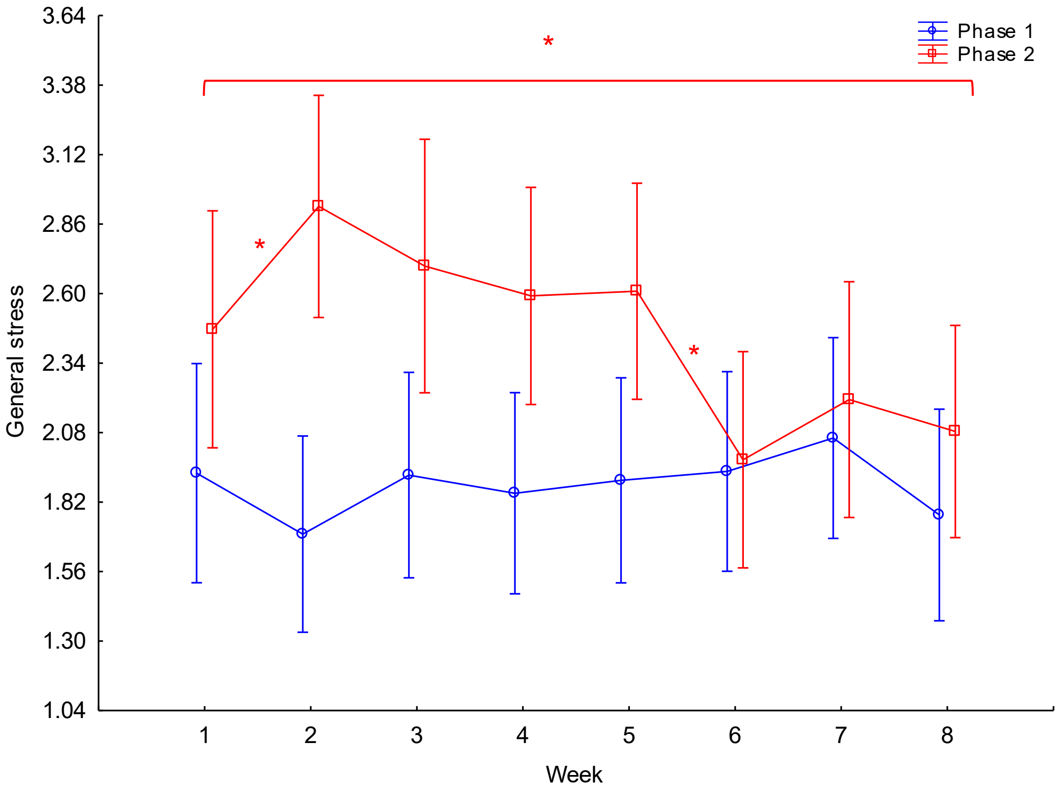
General stress (GS)

Phase 1

During P1, general stress (GS) stayed relatively constant for the total group, with no significant difference between the start point and the end point of P1 (p=0.39) (Figure 4.6). No significant difference between male and female dancers (p=0.78), or between the two levels (p=0.69) was observed.

Phase 2

A significant decrease in GS for the total group between week 1 and week 8 during P2 (p=0.05) was noted. After an initial increase in week 2 (p=0.03), the weekly GS states were lower towards the end of the phase; particularly in week 6, where a significant decrease was observed (p<0.01) (Figure 4.6). No significant difference in GS between male and female dancers (p=0.74), or between the two levels (p=0.26) were seen.



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.6 General stress for the total group over Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The P2 average was significantly higher than P1 (p<0.01) for the total group, with weekly scores differing significantly between the two phases (p<0.01), as illustrated in Figure 4.6. Both male and female dancers had significantly higher GS levels in P2 than in P1 (p<0.01). However, no significant difference was seen between either sex groups (p=0.09) or levels (p=0.23) for P1 and P2. Both the SP and PGA groups increased significantly from P1 to P2 (p<0.01; p=01).

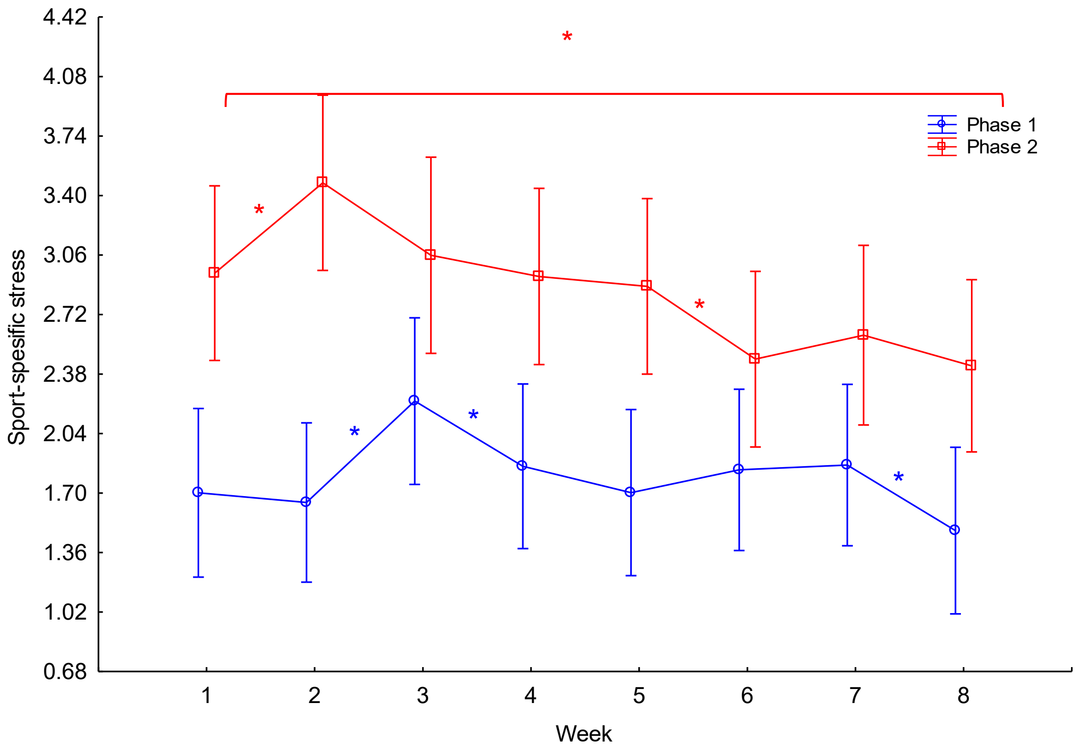
Sport-specific stress (SsS)

Phase 1

No significant change in sport-specific stress (SsS) was noted for the total group between weeks 1 and 8 of P1 (p=0.22) (Figure 4.7). However, the group indicated a statistically significant increase in SsS in week 3 (p=0.00), while less stress was observed in week 4 (p=0.03) and week 8 (p=0.02). There were no significant differences in SsS between sex groups (p=0.77) or levels (p=0.16) in P1.

Phase 2

Sport-specific stress was significantly lower at the end of P2 than the start of the phase (p<0.01) for the total group (Figure 4.7). Values increased significantly in week 2 (p<0.01). This was followed by a near-significant decrease in week 3 (p=0.07) and sustained decrease towards the end of the phase, with a significant decrease occurring in week 6 (p=0.02). Phase averages for P2 showed no significant difference between either sex groups (p=0.93) or levels (p=0.25).



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.7 Sport-specific stress of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

For the total group, SsS in P2 was significantly higher than P1 ($p<0.01$). The weekly average scores were significantly different for the two phases ($p<0.01$), as shown in Figure 4.7. Both male and female dancers had significantly higher SsS in P2 compared to P1 ($p<0.01$). No significant differences in phase averages between the two sex groups for the two phases were found ($p=0.81$). Both the SP group and PGA group had significantly more SsS in P2 than in P1 ($p<0.01$). No significant difference between the levels was found during the two phases ($p=0.75$).

General Recovery (GR)

Phase 1

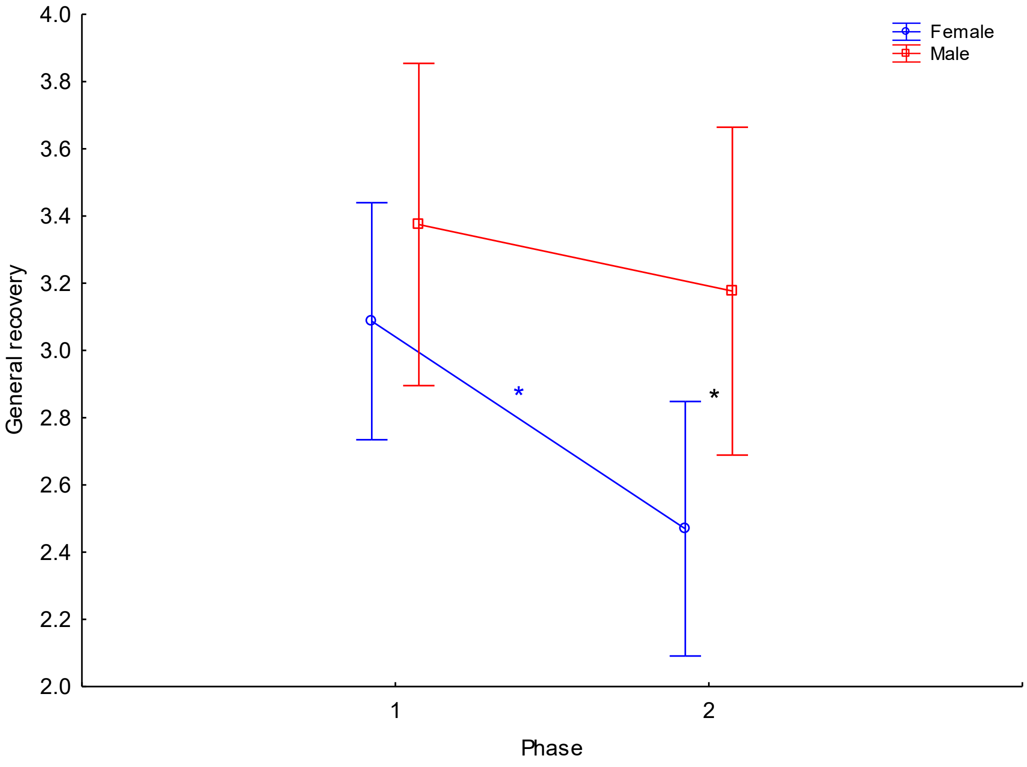
The total group showed no significant difference in general recovery (GR) between the start and end points of P1 ($p=0.63$). The weekly average trend stayed relatively constant, with only one significant decrease in week 3 ($p=0.03$). No significant differences in phase averages were found between either the two sex groups ($p=0.33$) or the two levels ($p=0.40$).

Phase 2

Although the total group's GR did not show a significantly higher score in week 8 compared to week 1 ($p=0.06$), a trend towards significance is clear. Multiple fluctuations were noted from week to week, with significant decrease in week 2 ($p=0.05$) and a significant increase in week 6 ($p=0.01$). While female dancers had significantly lower GR scores than male dancers in P2 ($p=0.03$), no significant difference in GR phase average was noted between levels ($p=0.96$).

Comparison between Phase 1 and Phase 2

The total group showed significant lower GR scores in P2 ($p<0.01$), with weekly scores over the two phases being significantly different from one another ($p<0.01$). Male dancers had no significant change in phase average from P1 to P2 ($p=0.14$), while female dancers showed significantly lower GR scores in P2 ($p<0.01$). sex groups differed significantly from each other in phase averages over the two phases ($p=0.02$), as illustrated in Figure 4.8. Both levels had significantly lower GR scores in P2 compared to P1 (SP p=0.01; PGA p<0.01). The phase averages for these two levels differed significantly from each other over the two phases (p=0.21).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.8 General recovery of male and female dancers for Phase 1 and Phase 2.

Sport-specific recovery (SsR)

Phase 1

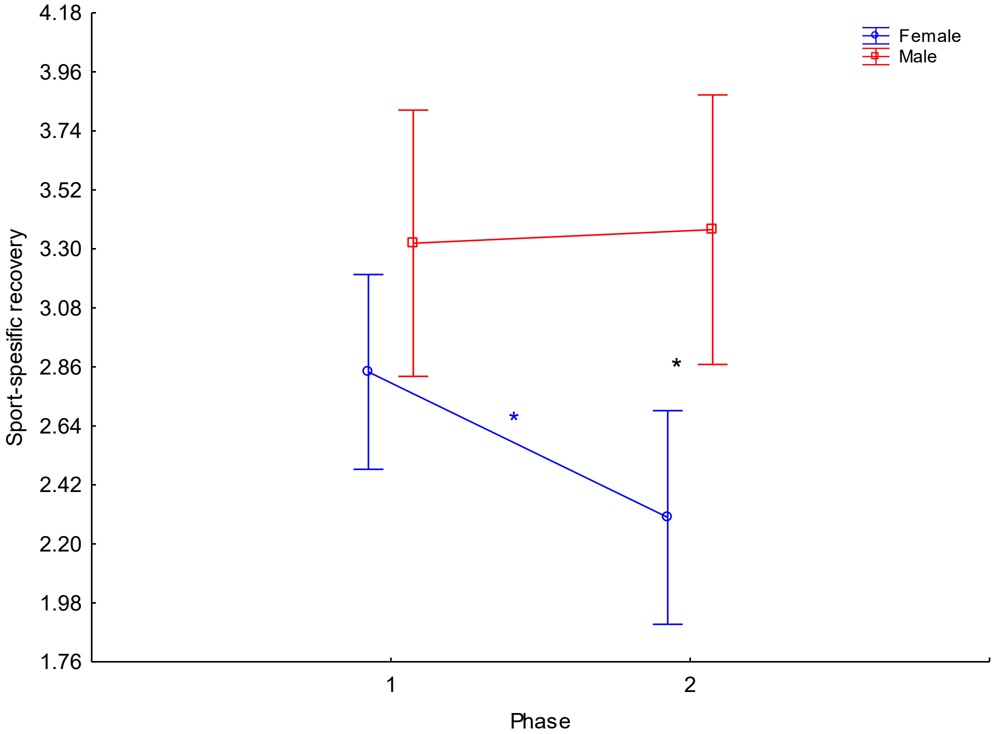
No significant differences in sport-specific recovery (SsR) were found for the total group (p=0.55), between sex groups (p=0.12) or between levels (p=0.84).

Phase 2

The total group showed no significant change in SsR between the start and end points for P2 (p=0.65), however a significantly lower SsR score was noted in week 5 (p=0.02). Female dancers had significantly lower SsR during P2 compared to male dancers (p<0.01), but no significant difference in phase average between the two levels was seen (p=0.20).

Comparison between Phase 1 and Phase 2

The total group showed significantly lower SsR scores in P2 (p=0.03). The SsR weekly scores in P1 and P2 did not differ significantly from each other (p=0.09). While male dancers had no significant changes from P1 to P2 (p=0.76), female dancers showed significantly lower SsR levels in P2 than in P1 (p<0.01). The sex groups differed significantly from each other over the two phases (p=0.01), as indicated in Figure 4.9. No significant change in phase average was seen in the SP group from P1 to P2 (p=0.52). However, PGA showed significantly lower SsR scores in P2 compared to P1 (p=0.02). There was no significant difference between the PGA group and SP group over the two phases (p=0.15).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.9 Sport-specific recovery of male and female dancers for Phase 1 and Phase 2.

Subscales

General stress^ (GS^)

Phase 1

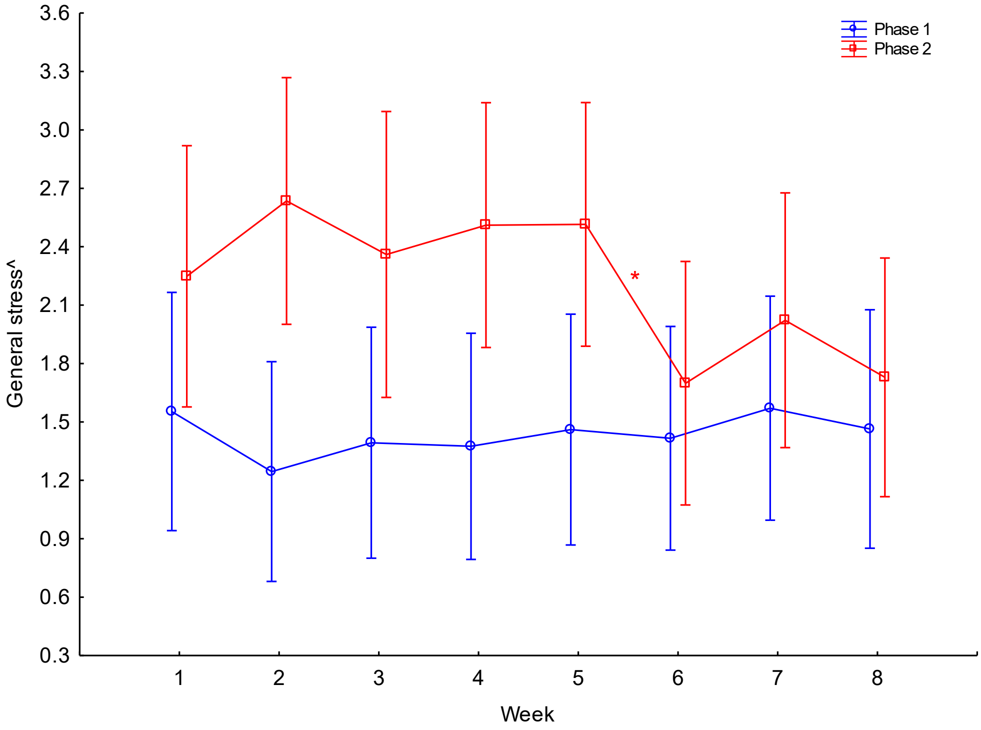
General stress (GS^) for the total group during P1 remained relatively constant, with no significant changes between weeks or between the start and end points of P1 (p=0.74). No significant differences regarding GS^ were observed between male and female dancers (p=0.68), or between the SP and PGA groups (p=0.74).

Phase 2

The week averages of week 8 and week 1 were not significantly different from one other for the total group (p=0.08). A significant decrease was observed in week 6 (p<0.01). Similar to P1, no significant differences in GS^ were observed between male and female dancers (p=0.71), or between the SP and PGA groups (p=0.82).

Comparison between Phase 1 and Phase 2

Phase 2 showed significantly higher GS^ than P1 for the total group (p<0.01), male and female dancers (p<0.01), and both levels (p<0.01). Weekly scores in P1 differed significantly from that of P2 for the total group (p=0.02). Neither the sex groups (0.97) nor levels (p=0.88) showed significant differences from each other over the two phases. Figure 4.10 shows the weekly scores of the total group for each phase.



Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase ($p \leq 0.05$).

Figure 4.10 General stress^ of the total group for Phase 1 and Phase 2.

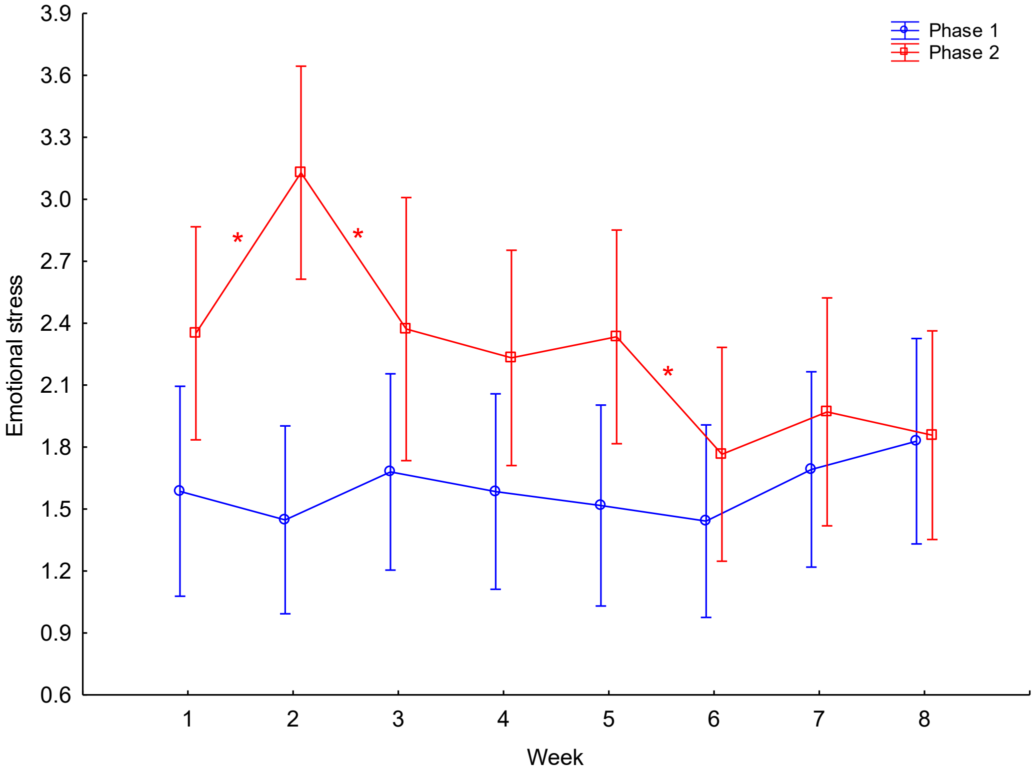
Emotional stress (ES)

Phase 1

No significant difference from week 1 to week 8 of P1 were noted for the total group's emotional stress (ES) (p=0.35). In addition to this, the weekly trend remained relatively constant throughout the phase (Figure 4.11). No significant differences in ES phase average were noted between male and female dancers (p=0.43), or between the levels (p=0.41).

Phase 2

Emotional stress for the total group showed no significant difference between week 1 and week 8 in P2 (p=0.07). Despite an initial significant increase in week 2 (p<0.01), a clear downward trend was noted through P2, with one significant decrease occurring in week 3 (p=0.02) and another in week 6 (p=0.03) (Figure 4.11). No significant differences in the phase average of ES were noted between male and female dancers (p=0.36), or between levels (p=0.35).

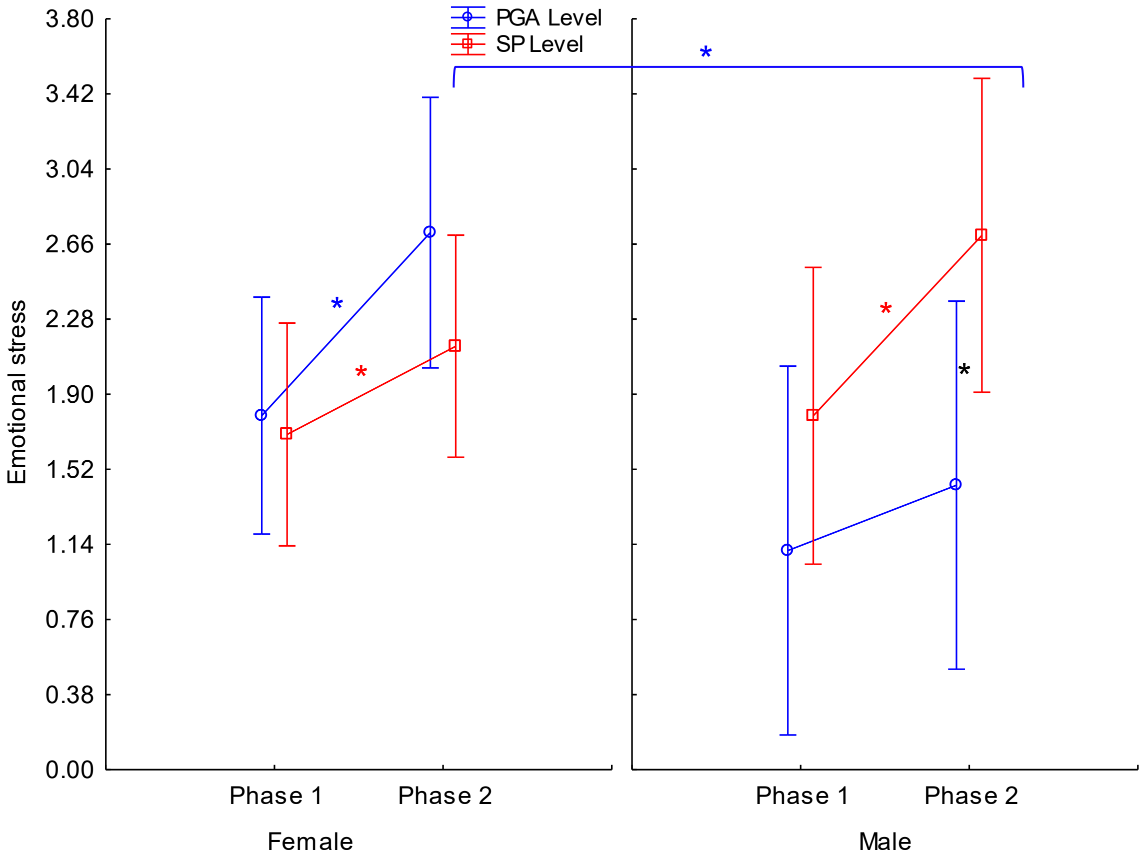


Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.11 Emotional Stress of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The total group ($p<0.01$), male and female dancers ($p<0.01$), and both levels ($p<0.01$) had significantly more ES during P2 compared to P1. A significant difference between the weekly scores of the two phases was noted ($p<0.01$), as shown in Figure 4.11. No significant difference between the two sex groups ($p=0.78$) or between the two levels ($p=0.82$) was noted across the phase averages for P1 and P2. However, when a comparison between sex - specific levels was carried out, male levels and female levels differed significantly from one another over the two phases ($p=0.03$). Figure 4.12 shows the differences in ES between inter- and intra-sex levels over P1 and P2.



Note: * * indicates a significant difference between the two phases at the end points of the line, of the particular level (p≤0.05). * indicates a significant difference between the two levels' phase averages during the particular phase.

Figure 4.12 Emotional stress of sex-specific levels during Phase 1 and Phase 2.

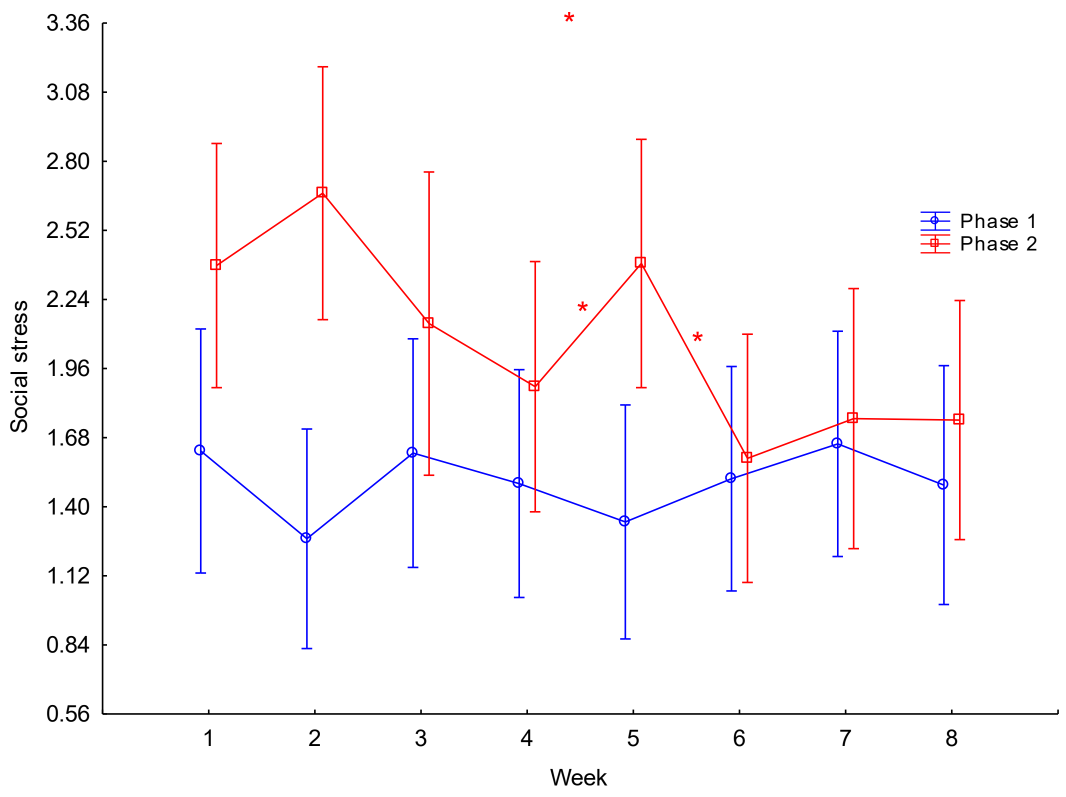
Social stress (SS)

Phase 1

There was neither a significant difference in the social stress (SS) for the total group between the start and the finish of P1 (p=0.58), nor significant fluctuations between weeks. No significant differences in phase average of P1 existed between male and female dancers (p=0.55), or between PGA and SP groups (p=0.24).

Phase 2

The total group ended P2 with a significantly lower SS value than at the beginning of the phase (p=0.01). Social stress increased significantly in week 5 (p=0.05), but decreased in week 6 (p<0.00). Figure 4.13 shows the total group's weekly scores over P2. Neither the sex groups (p=0.13) nor the levels (p= 0.31) differed significantly from each other in terms of P2 phase averages.

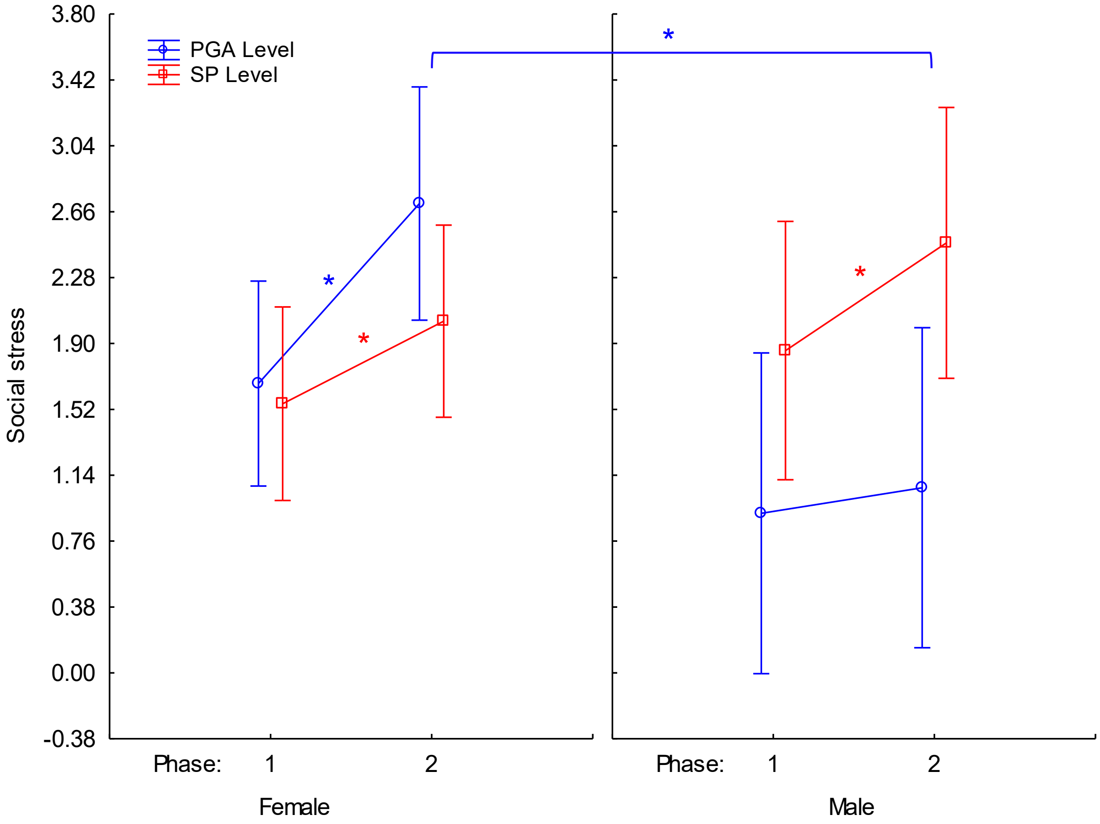


Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.13 Social stress of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The total group (p<0.01), male and female dancers (p=0.04, p<0.01), and PGA and SP groups (p<0.01) all had significantly more ES during P2 than during P1. The weekly scores of the total group differed significantly between P1 and P2 (p<0.01) and can be seen in Figure 4.13. No significant difference between male and female dancers (p=0.11) or between levels (p=0.85) was observed over the two phases. However, when sex-specific levels were compared, male and female SP and PGA groups differed significantly over the two phases (p=0.03). Figure 4.14 shows the inter- and intra-sex level differences of SS for P1 and P2.



Note: * * indicates a significant difference between the two phases at the end points of the line, of the particular level (p≤0.05).

Figure 4.14 Social stress of sex-specific levels during Phase 1 and Phase 2.

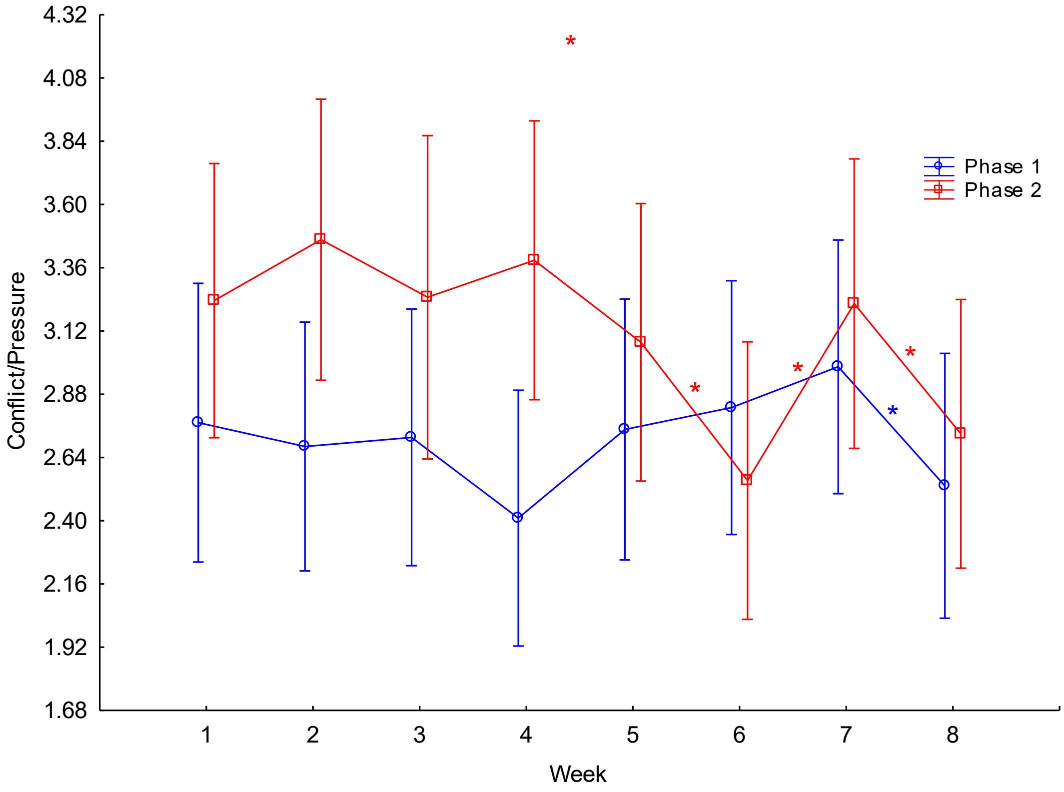
Conflicts/Pressure (C/P)

Phase 1

While no significant difference in terms of conflicts/pressure (C/P) was seen between week 1 and week 8 (p=0.30), a significantly lower C/P average was seen in week 8 (p=0.03) (Figure 4.15). No significant differences in phase average of C/P for P1 were observed between male and female dancers (p=0.95), or between PGA and SP groups (p=0.55).

Phase 2

At the end of P2, the total group showed a significantly lower C/P weekly average compared to the start the phase (p=0.03). Significant weekly fluctuations were noted during P2, as illustrated in Figure 4.15. A decrease in C/P values in week 6 (p=0.02) was followed by an increase in week 7 (p=0.01) and another decrease in week 8 (p=0.03). No significant differences in the P1 phase average of C/P were seen between male and female dancers (p=0.49), or between PGA and SP groups (p=0.10).

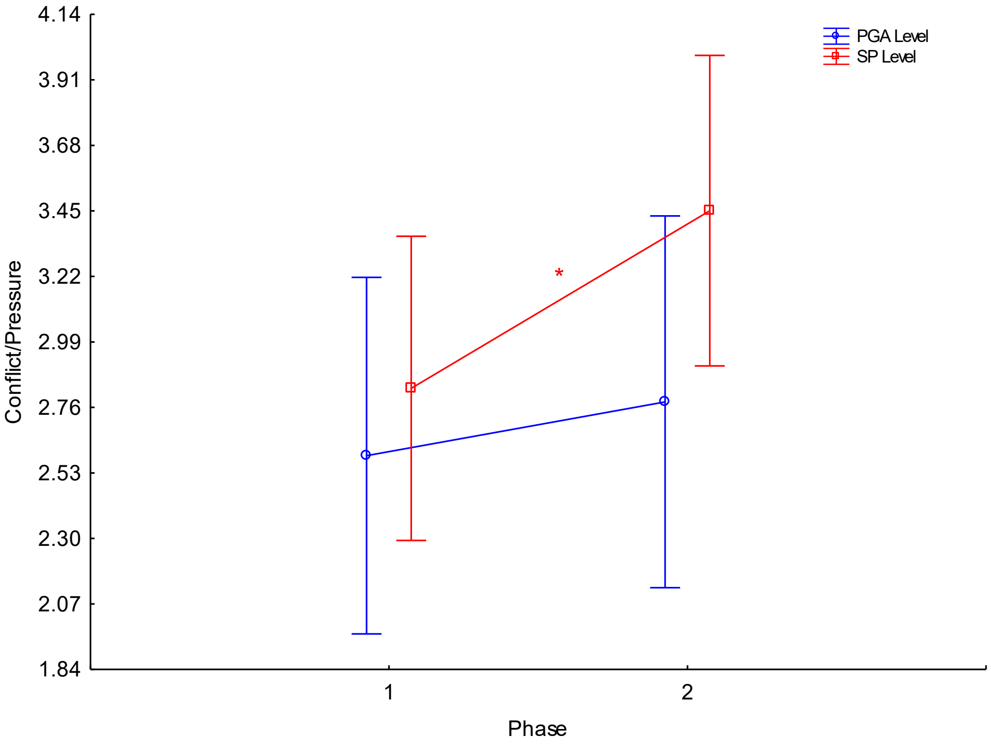


Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase ($p \leq 0.05$).

Figure 4.15 Conflict/Pressure of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The total group had significantly more C/P during P2 than P1 (p=0.01) and weekly scores differed significantly between phases (p<0.01). No significant change was evident in the C/P average for female dancers from P1 to P2 (p=0.18). However, male dancers showed a significant increase in the C/P experienced between phases (p=0.03). The phase averages for the two sex groups were not significantly different from each other (p=0.37). In terms of levels, the SP group's C/P was significantly higher in P2 than in P1 (p<0.01), while the PGA group's average did not change significantly (p=0.44). Even so, no significant difference between PGA and SP groups is noted over the two phases (p=0.17). Figure 4.16 shows the differences between levels.



Note: * * indicates a significant difference between Phase 1 and Phase 2 of the particular level (p≤0.05),

Figure 4.16 Conflict/Pressure of the levels for Phase 1 and Phase 2.

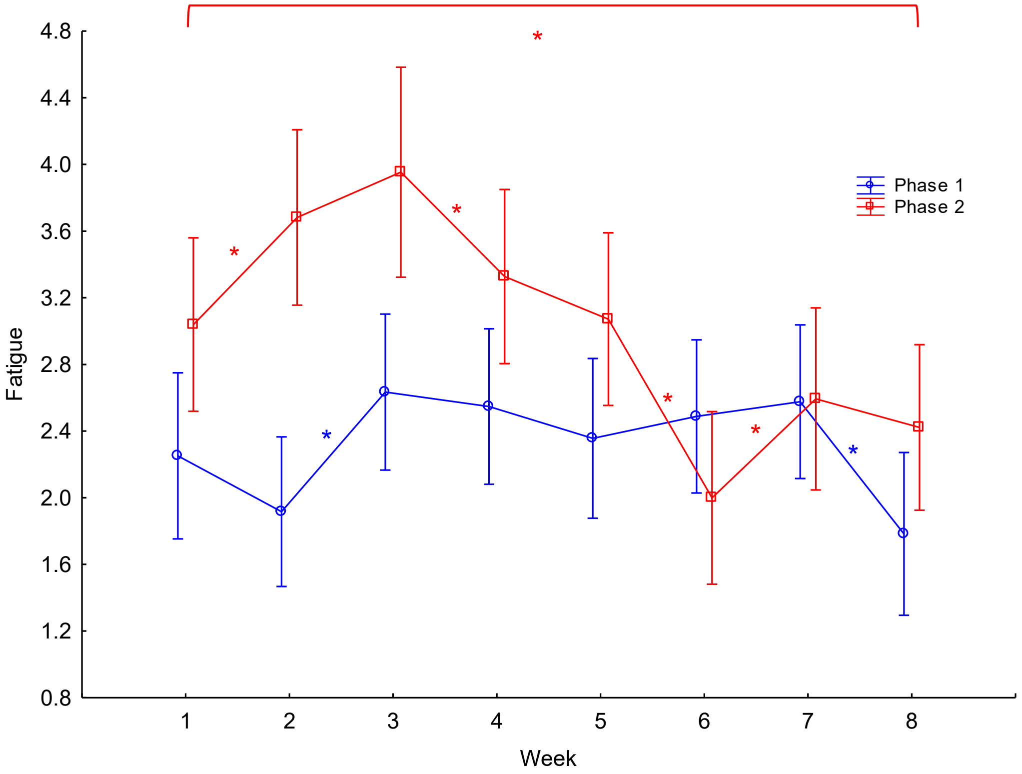
Fatigue (F)

Phase 1

The P1 phase average indicates a near-significant decrease in fatigue (F) (p=0.06) between the beginning and end of P1, with a significant increase in week 3 (p<0.01) and a decrease in week 8 (p<0.01) (Figure 4.17). No significant differences in phase averages for either sex groups (p=0.35) or levels (p=0.77) were observed in P1.

Phase 2

Levels of F were significantly lower at the end of P2 than at the beginning of the phase (p=0.02). Significant inter-week fluctuations were noted, with increases in week 2 (p=0.01) and week 7 (p=0.03), and decreases in week 4 (p=0.04) and week 6 (p<0.01) (Figure 4.17). No significant differences in phase averages for either sex groups (p=0.13) or levels (p=0.39) were observed.



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.17 Fatigue of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The phase average showed that the total group had significantly more F in P2 compared to P1 (p<0.01). Weekly scores differed significantly between the two phases (p<0.01). Figure 4.17 shows the total group's weekly scores across two phases. No significant differences in phase averages between sex groups were observed (p=0.44). Male (p<0.01) and female (p=0.02) dancers both showed significantly more F in P2 compared to P1. While the PGA group indicated no significant change in phase average from P1 to P2 (p=0.09), the SP group showed significantly more F in P2 compared to P1 (p<0.01). PGA and SP groups differed significantly from each other over the two phases (p=0.20).

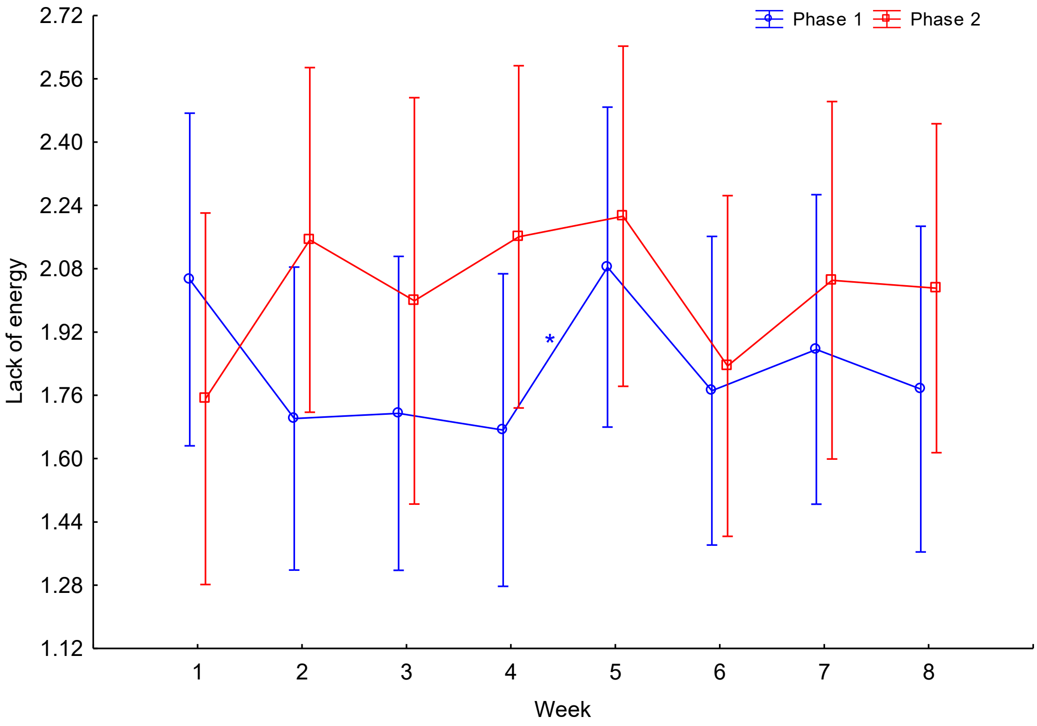
Lack of energy (LoE)

Phase 1

There was no significant difference in lack of energy (LoE) between the beginning and end of P1 (p=0.17) for the total group. Although not significant, the reduced LoE scores in week 2 had a trend towards significance (p=0.06). A significant increase was observed in week 5 (p=0.02). No significant differences between male and female dancers (p=0.52), or between levels (p=0.52) were observed during P1.

Phase 2

The total group showed no significant difference between the start and end points of P2 (p=0.21). A clear trend toward significance was seen in the lower scores for LoE of the total group in week 6 (p=0.06). No significant differences in LoE were seen between male and female dancers (p=0.19), or between levels (p=0.21) during P2.

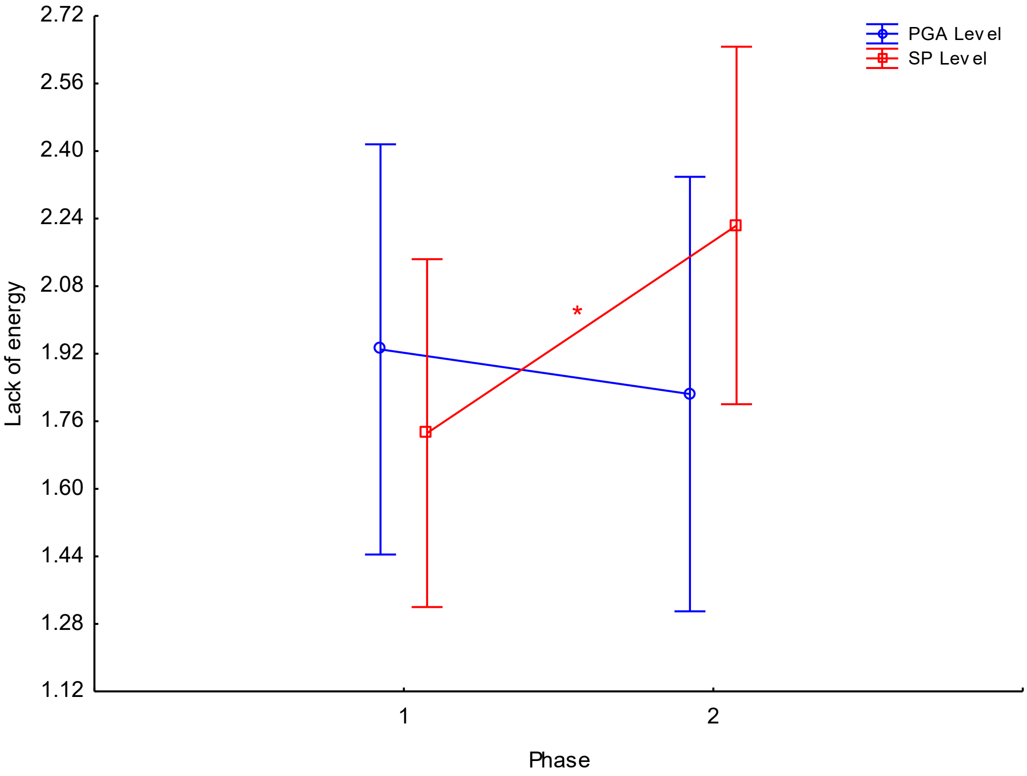


Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.18 Lack of energy of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

Neither phase averages nor weekly scores of LoE in P1 and P2 differed significantly for the total group (p=0.09; p=0.14). Male dancers had no significant changes in average LoE from P1 to P2 (p=0.68), while female dancers had a significant increase in LoE scores from P1 to P2 (p=0.03). Even so, phase averages of male and female dancers did not differ significantly from each other over the two phases (p=0.28). Levels were significantly different from each other over the two phases (p=0.01). The SP group had significantly higher LoE scores in P2 compared to P1 (p<0.01), while the PGA group showed no significant change of phase average (p=0.55). Figure 4.19 depicts the differences between levels over the two phases.



Note: * indicates a significant difference between Phase 1 and Phase 2 of the SP level (p≤0.05),

Figure 4.19 Lack of energy of the PGA and SP groups for Phase 1 and Phase 2.

Physical complaints (P/C)

Phase 1

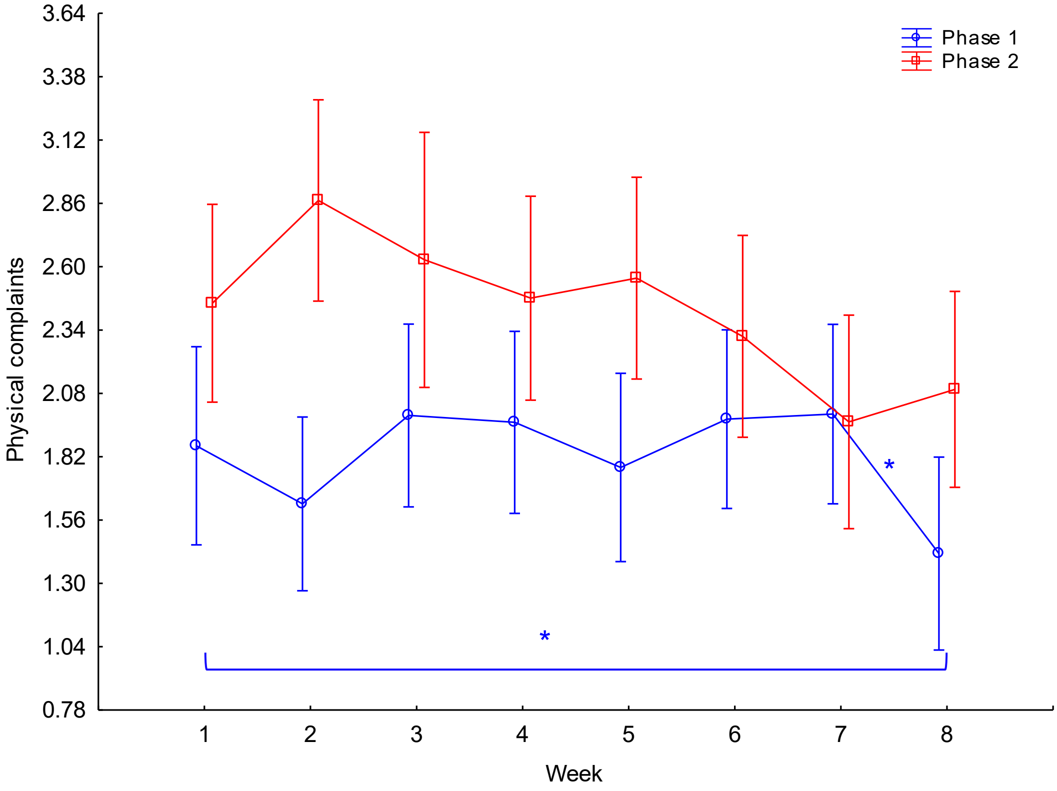
The total group had significantly fewer physical complaints (P/C) in week 8 compared to week 1 (p=0.05). Weekly averages remained relatively constant throughout P1, with a clear increase towards significance in week 3 (p=0.06) and a significant decrease in week 8 (p=0.01). No significant differences in P/C phase averages for either sex groups (p=0.93) or levels (p=0.85) were noted in P1.

Phase 2

No significant difference in weekly average P/C for the total group was found between the start and finish points of P2 (p=0.12). A predominantly downward trend was followed after an initial increase in week 2 (p=0.06). No significant differences in P/C were observed between male and female dancers (p=0.92), or between levels (p=0.56) during P2.

Comparison between Phase 1 and Phase 2

Phase 2 showed a significantly higher P/C phase average for the total group compared to P1 (p<0.01). The weekly scores differed significantly over the two phases (p<0.01), as illustrated in Figure 4.20. Phase averages for both sex groups (p<0.01) and both levels (p<0.01) had significantly higher levels of P/C during P2 compared to P1. Male and female dancers did not differ significantly from each other over the two phases (p=0.98). No statistical differences existed between the two levels over the two phases (p=0.29).



Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.20 Physical complaints of the total group for Phase 1 and Phase 2.

Success (S)

Phase 1

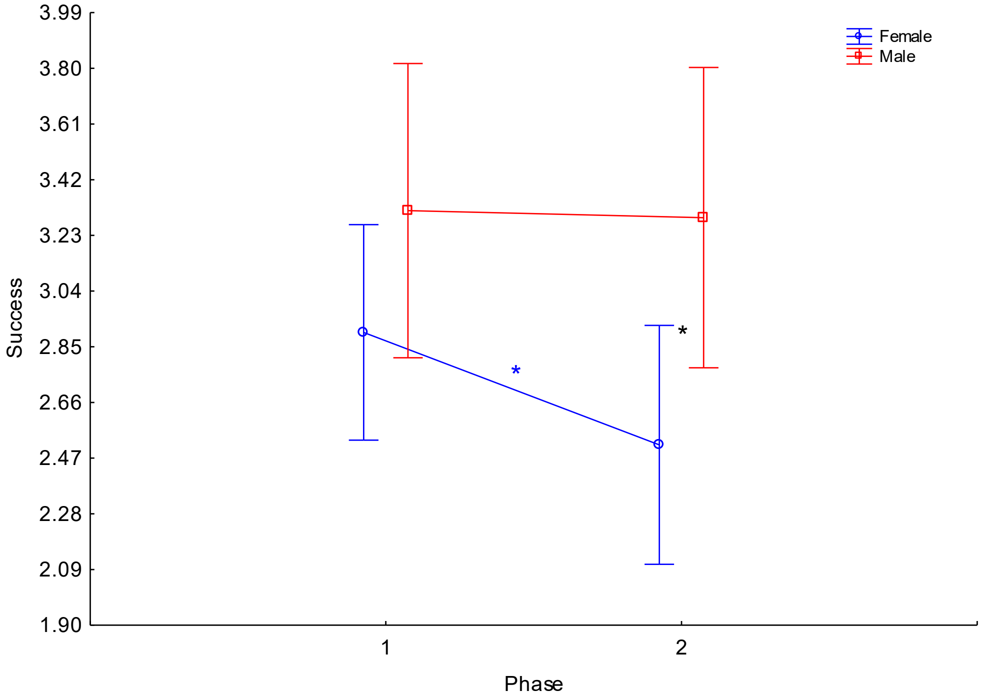
No significant difference in weekly average success (S) was noted between the start and end of P1 for the total group (p=0.20). In addition to this, there was no significant difference between sex groups (p=0.18) or levels (p=0.69).

Phase 2

The weekly average for the total group (p=0.75) between the beginning and end of P2 showed no significant difference. A significant decrease in the weekly average was noted in week 2 (p=0.02). Male dancers indicated significantly higher S scores during P2 compared to female dancers (p=0.02). No significant difference in S between levels were noted (p=0.23)

Comparison between Phase 1 and Phase 2

The total group's S phase average showed no significant difference (p=0.08). Weekly scores for the two phases were not statistically different form each other (p=0.25). While male dancers' S phase averages remained relatively unchanged from P1 to P2 (p=0.89), female dancers' S averages decreased significantly from P1 to P2 (p=0.01). Figure 4.21 shows the difference between the sex groups for both phases. No significant differences between male and female dancers' phase averages across the two phases were seen (p=0.12). The same can be said for the levels, where both the PGA and SP groups phase averages remained relatively constant from P1 to P2 (p=0.18; p=0.23). There was no significant difference between the two levels over the two phases (p=0.74).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.21 Success of male and female dancers during Phase 1 and Phase 2.

Social recovery (SR)

Phase 1

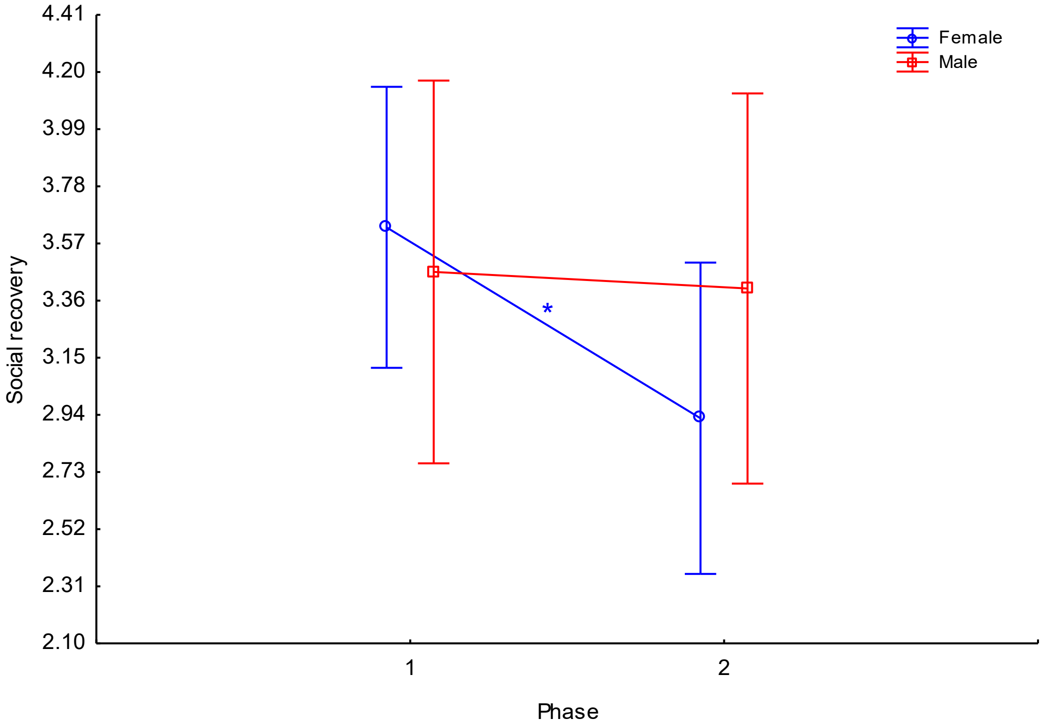
The total group exhibited no significant difference in social recovery (SR) between the beginning and end points of P1 (p=0.73). A clear trend towards significance can be observed in the increase in the SR average in week 5 (p=0.06) and significant increase in week 8 (p=0.04). No significant differences in SR phase averages for either the sex groups (p=0.70) or levels (p=0.24) were noted in P1.

Phase 2

No significant difference in the weekly average for the total group was seen from the beginning to the end of P2 (p=0.13) or between any consecutive weeks. No significant differences between SR phase averages of sex groups (p=0.29) or levels (p=0.78) were noted during P2.

Comparison between Phase 1 and Phase 2

The total group showed significantly lower SR phase average scores in P2 compared to P1 (p=0.02). The weekly scores for the total group in P1 and P2 did not differ significantly from one another over the two phases (p=0.10). Male dancers showed no significant change in SR phase average between phases (p=0.80), however female dancers showed a significant decrease in SR phase average from P1 to P2 (p<0.01). The sex groups were significantly different from each other in terms of SR across the two phases (p=0.05), as illustrated in Figure 4.22. Social recovery for the SP group remained relatively unchanged from P1 to P2 in terms of SR phase averages (p=0.31), while the PGA group's phase average decreased significantly from P1 to P2 (p=0.03). The two levels did not significantly differ from each other over the two phases (p=0.25).



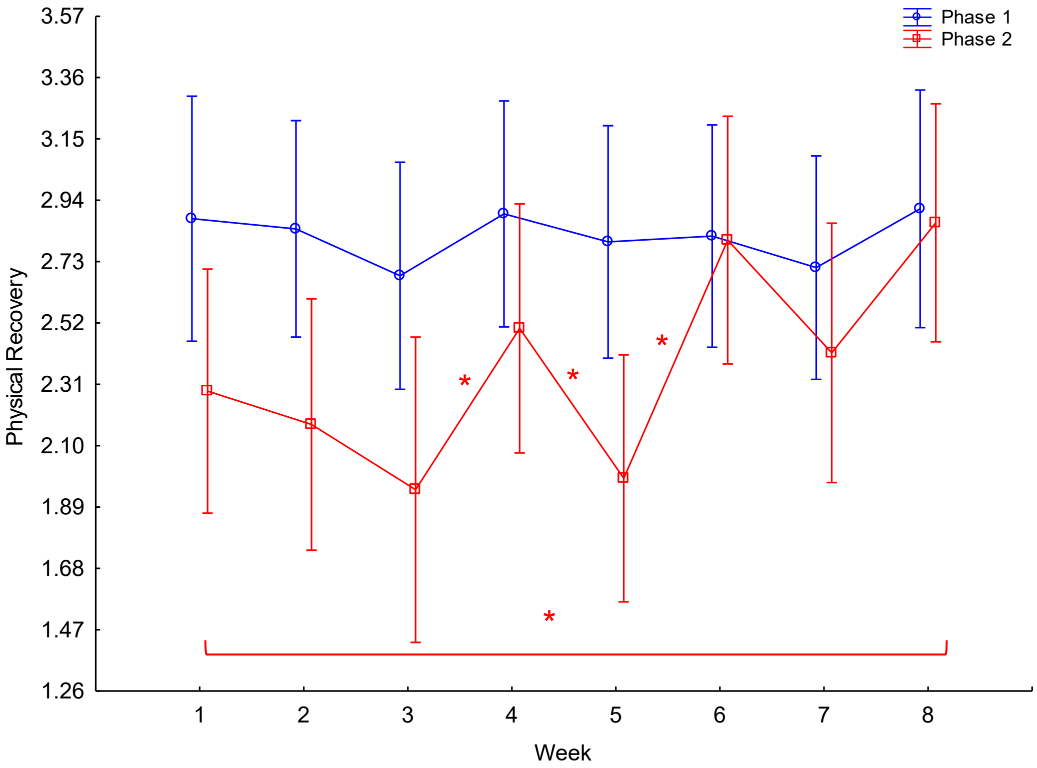
Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers ($p \leq 0.05$).

Figure 4.22 Social recovery of male dancers and female dancers during Phase 1 and Phase 2.

Physical recovery (PR)

Phase 1

The weekly averages of physical recovery (PR) showed so significant difference in the total group from beginning to end of P1 (p=0.88) or between any of the following weeks (Figure 4.23). No significant difference between PR phase averages of sex groups (p=0.22) or levels (p=0.60) was noted during P1.



Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase ($p \leq 0.05$).

Figure 4.23 Physical recovery of the total group for Phase 1 and Phase 2.

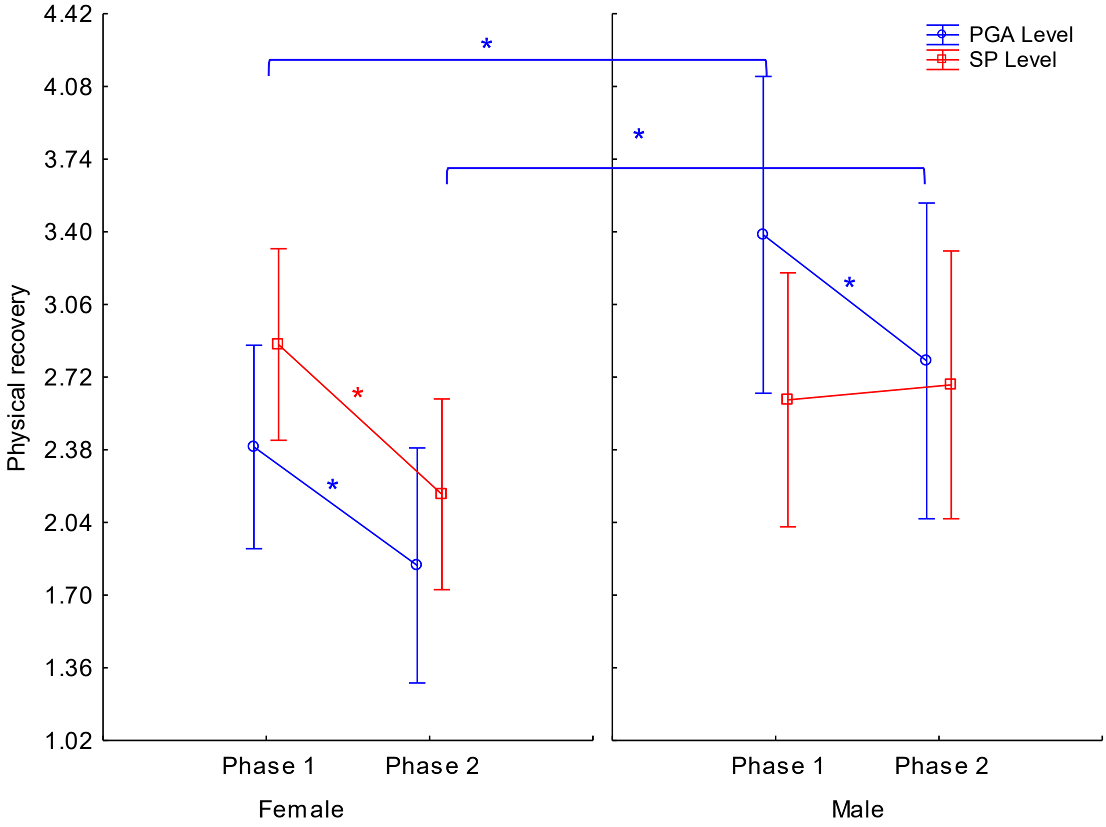
Phase 2

When considering weekly averages, P2 ended with significantly more PR compared to the start of the phase (p=0.01) for the total group. A significant increase in the weekly average was noted in week 4 (p=0.05). This was followed by a decrease in week 5 (p=0.03) and further increases in week 6 (p<0.01) and week 8 (p=0.05). Figure 4.23 shows the weekly fluctuations for the total group. The phase average for female dancers showed significantly less PR during P2 compared to male dancers (p=0.02). No significant difference in PR phase averages was seen between the two levels (p=0.70).

Comparison between Phase 1 and Phase 2

The total group's phase average showed significantly lower PR scores in P2 compared to P1 (p<0.01). The weekly scores for PR in P1 were significantly different from those in P2 (p=0.02). Figure 4.22 shows the different weekly scores for the total group in P1 and P2.

Male dancers had relatively similar phase average scores (p=0.09) for PR for P1 and P2, while female dancers showed significantly less PR in P2 compared to P1 (p<0.01). The differences between sex groups over the two phases were not significant (p=0.06), but a tendency towards significance is clear. Both the SP and PGA groups showed significantly less PR in P2 compared to P1 (p=0.01; p<0.01). No statistical difference existed between the two levels over the two phases (p=0.18). However, when a comparison between sex-specific levels was carried out, male and female SP and PGA groups differed significantly from one another over the two phases (p=0.04). Figure 4.24 depicts the differences in these inter- and intra-sex levels.



Note: * * indicates a significant difference between the two phases at the end points of the line, of the particular level (p≤0.05).

Figure 4.24 Physical recovery of sex-specific levels groups during Phase 1 and Phase 2.

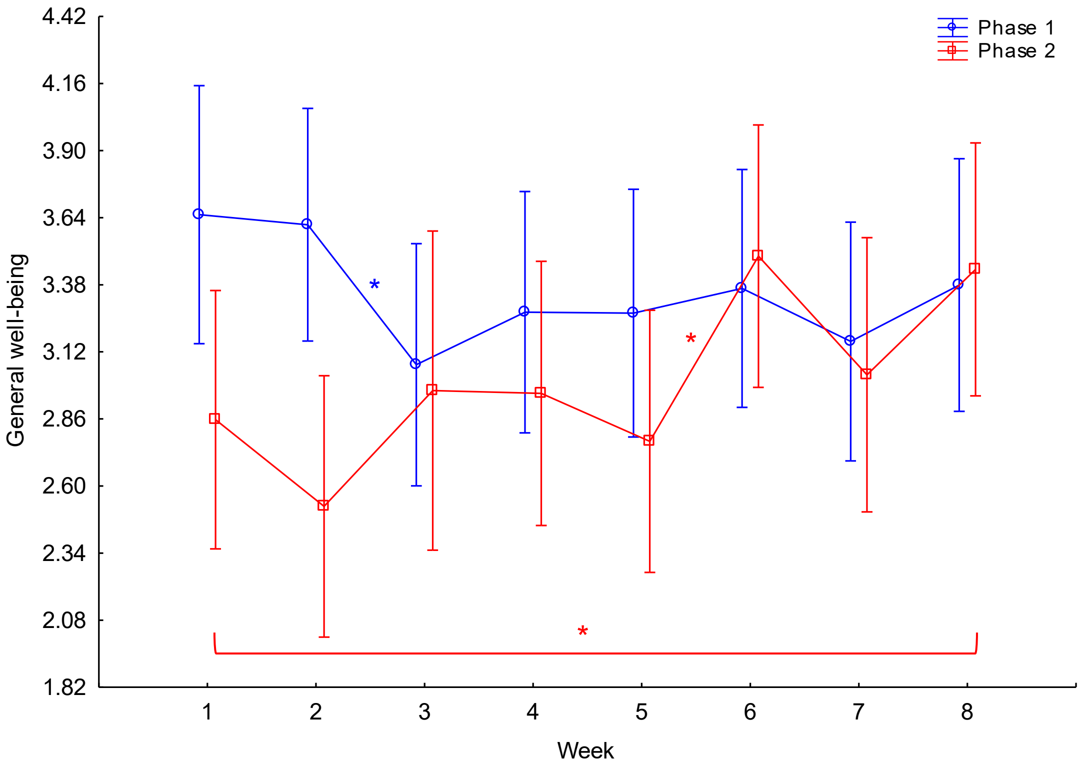
General well-being (GWb)

Phase 1

The total group showed no significant difference in weekly average of general well-being (GWb) between week 1 and week 8 for P1 (p=0.27). Significantly lower GWb scores were noted in week 3 (p=0.01) (Figure 4.25). Neither the phase averages of male and female dancers (p=0.49) nor those of the two levels (p=0.54) differed significantly from each other in P1.

Phase 2

A significant increase in GWb existed for the total group between week 1 and week 8 (p=0.02), and a significantly higher total group GWb score was seen in week 6 (p=0.01) (Figure 4.25). Female dancers had significantly lower GWb scores compared to male dancers in P2 in terms of phase averages (p=0.04). The two levels showed no significant difference in GWb from each other in P2 (p=0.48).

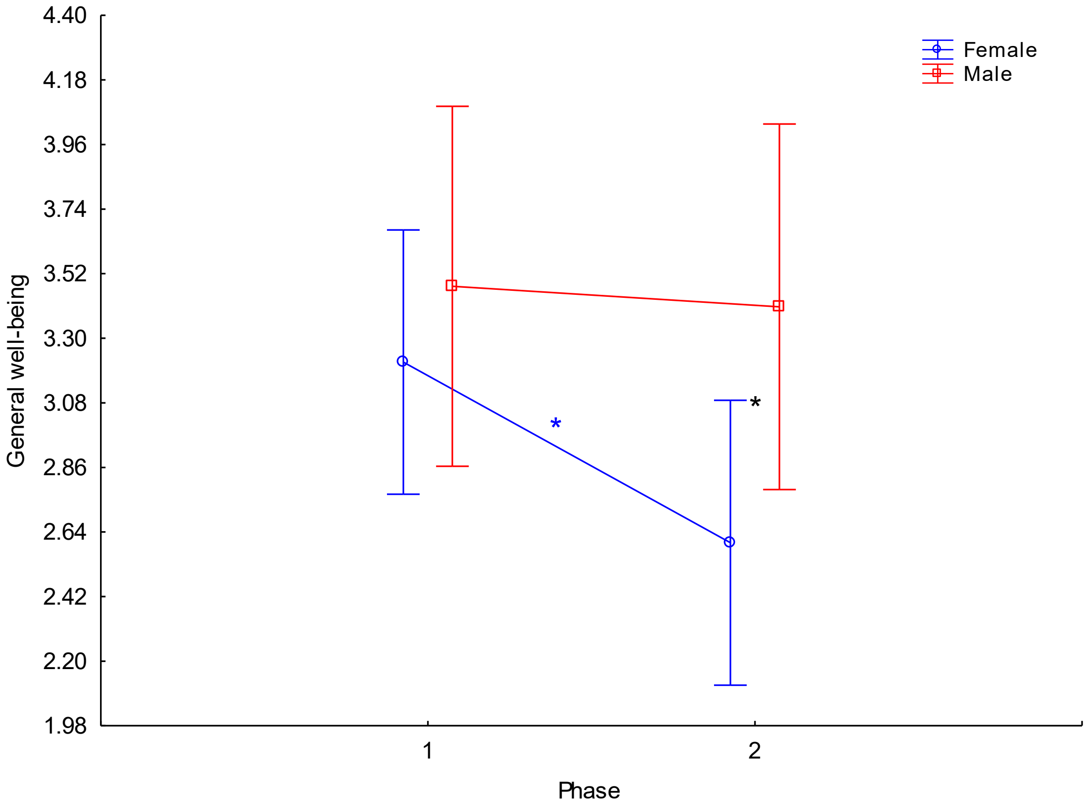


Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.25 General well-being of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

The total group had significantly lower GWb scores in P2 compared to P1 ($p<0.01$) and the weekly scores for P1 and P2 differed significantly from each other ($p<0.01$). Male dancers' GWb phase average stayed relatively constant from P1 to P2 ($p=0.68$), while female dancers' phase average decreased significantly from P1 to P2 ($p<0.01$). GWb weekly scores for the two sexes differed significantly over the two phases ($p=0.02$), as illustrated in Figure 4.26. The PGA group's phase average during P2 was not significantly lower than P1 ($p=0.07$), however a clear tendency towards significance was noted. The SP group's phase average in P2 was significantly lower than that of P1 ($p=0.01$). The phase averages of the levels did not differ significantly from each other ($p=0.86$).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers ($p \leq 0.05$), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.26 General well-being of male dancers and female dancers during Phase 1 and Phase 2.

Sleep quality (SQ)

Phase 1

The total group's weekly averages of sleep quality (SQ) between the start and end points of P1 showed no significant difference ($p=0.62$). The total group had significantly lower SQ scores in week 3 ($p=0.01$) and week 6 ($p=0.03$) and demonstrated a tendency towards significance with higher SQ scores in week 8 ($p=0.07$). No significant differences were observed between male and female dancers ($p=0.15$), or between levels ($p=0.62$) in P1.

Phase 2

The total group showed no significant difference in week averages between the start and end of P2 ($p=0.79$). The total group showed significantly lower SQ scores in week 2 ($p<0.01$), after which the weekly average consistently increased non-significantly from weeks 3 to 7. However, a significant difference existed between week 3 and weeks 5 to 8 ($p=0.03$; $p=0.01$). Both sex groups ($p=0.07$) and levels ($p=0.38$) showed no significant difference in SQ scores during P2. Female dancers, however, had a clear tendency towards a significantly lower phase average compared to male dancers ($p=0.07$).

Comparison between Phase 1 and Phase 2

Both the total group ($p<0.01$) and sex groups (male $p=0.04$; female $p<0.01$) indicated significantly lower SQ scores in P2 compared to P1. For the total group, weekly scores were significantly different between the two phases ($p<0.01$). No significant differences were seen over the two phases between the sex groups ($p=0.58$). Despite the absence of a significant decrease in the SP group's phase average from P1 to P2 ($p=0.06$), a clear trend towards significance was noted. The PGA group's phase average decreased significantly from P1 to P2 ($p<0.01$). The levels did not differ significantly from each other over the two phases ($p=0.15$).

Disturbed breaks (DB)

Phase 1

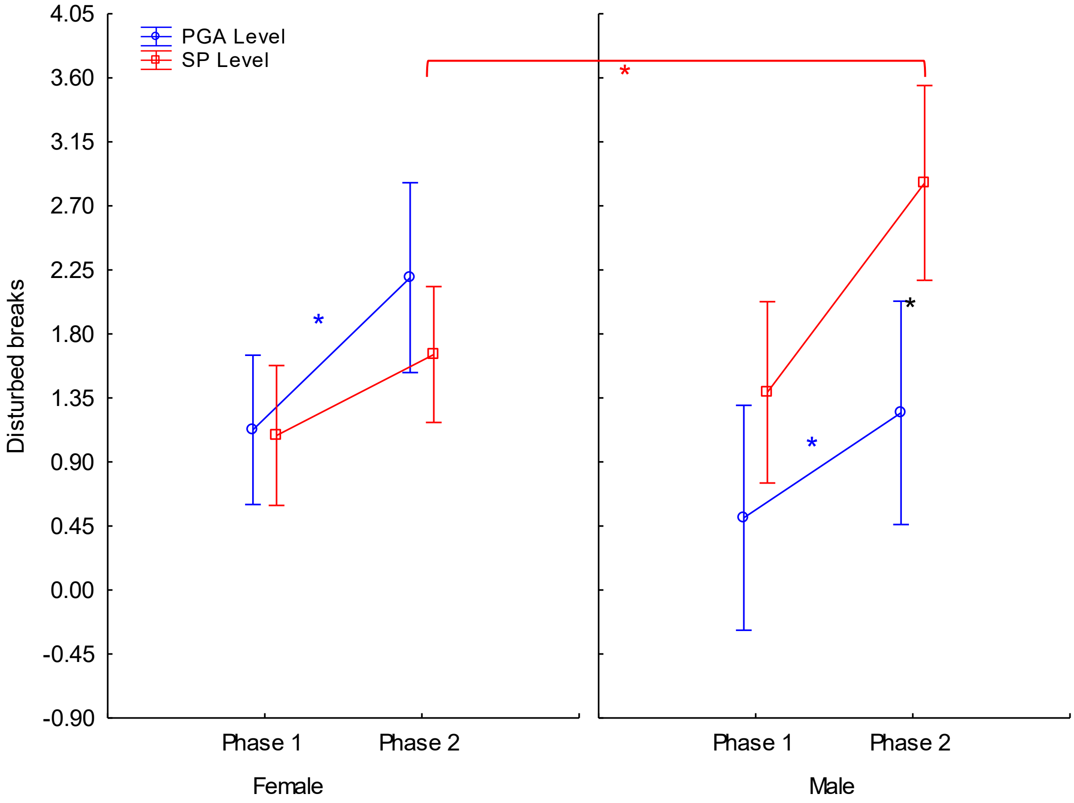
For the total group, the weekly averages of disturbed breaks (DB) remained relatively constant throughout P1, with no significant difference found between week 1 and 8 (p=0.77), or between any two consecutive weeks. No significant differences were noted for the DB phase average in P1 between either the sex groups (p=0.61) or levels (p=0.18).

Phase 2

Similar to P1, no significant difference was found in the DB weekly average between week 1 and week 8 (p=0.97). Significantly more DB was seen in week 2 (p<0.01), decreasing in week 4 (p=0.05). A tendency towards significantly more DB was seen again in week 5 (p=0.07), decreasing again in week 6 (p= 0.03). No significant difference between DB phase averages of the two sex groups (p=0.70) or levels (p=0.10) existed during P2.

Comparison between Phase 1 and Phase 2

The total group (p<0.01), male and female dancers (p<0.01), and both levels (p<0.01) reported significantly higher DB scores during P2 compared to P1. The difference in weekly scores for the two phases were not significantly different from each other (p=0.07). The phase averages were similar for the two sex groups (p=0.36), as well as the two levels (p=0.71). However, when a comparison between sex-specific levels was carried out, male and female SP and PGA groups differed significantly from one another over the two phases (p=0.06). Figure 4.27 shows the inter- and intra-sex level differences over P1 and P2.



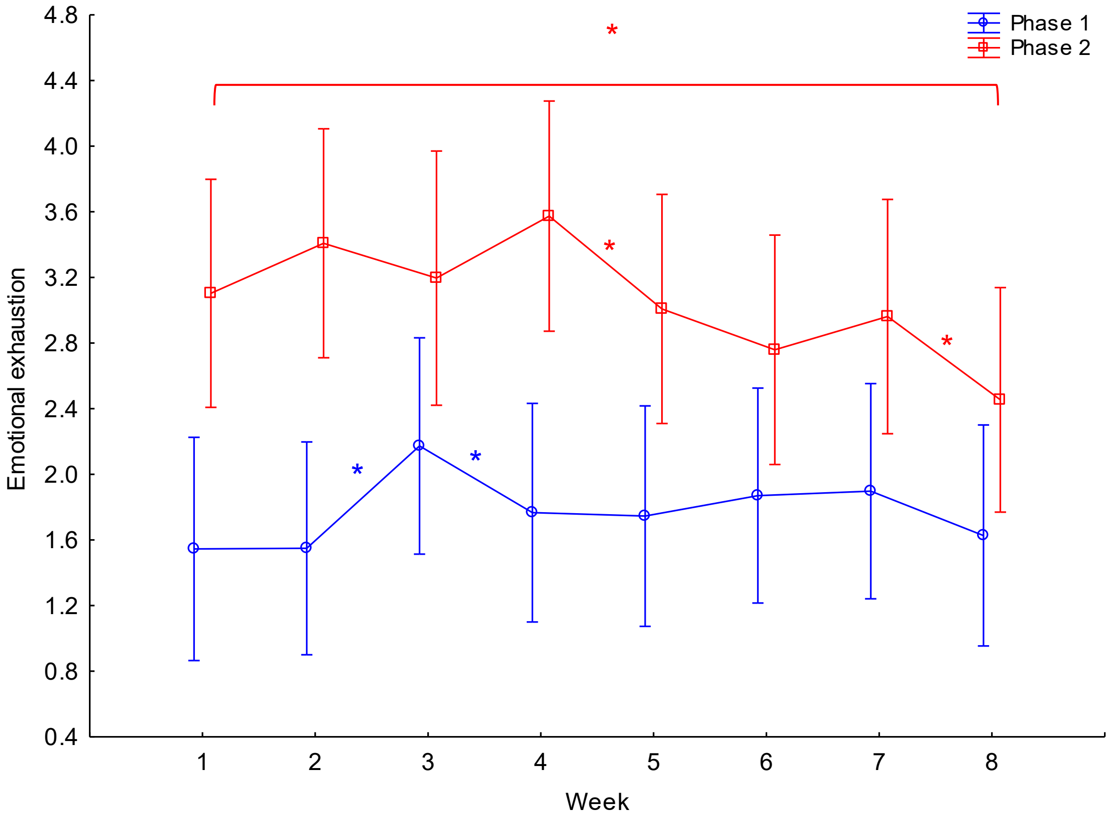
Note: * * indicates a significant difference between the two phases at the end points of the line, of the particular level (p≤0.05). * indicates a significant difference between the two levels' phase averages during the particular phase.

Figure 4.27 Disturbed breaks of sex-specific levels groups during Phase 1 and Phase 2.

Emotional exhaustion (EX)

Phase 1

The weekly averages of emotional exhaustion (EX) remained relatively constant throughout P1 for the total group, with no significant difference noted between the beginning and end points of P1 (p=0.73). For the total group, significantly more EX was seen in week 3 (p<0.01), while less EX was observed in week 4 (p=0.05) of P1 (Figure 4.28). No significant difference between male and female dancers' EX phase averages were seen in P1 (p= 0.73). The PGA group's EX was not significantly lower than that of SP group's (p=0.09).



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.28 Emotional exhaustion of the total group for Phase 1 and Phase 2.

Phase 2

During P2, the weekly average of EX was significantly less at the end of P2 compared to the start (p=0.01), with the phase predominantly following a gradual downward slope. Significantly less EX was noted in week 5 (p=0.02) and again in week 8 (p=0.04). The significant weekly fluctuations of the total group are depicted in Figure 4.27. Both sex groups (p=0.63) and levels (p=0.51) reported similar EX phase averages during P2.

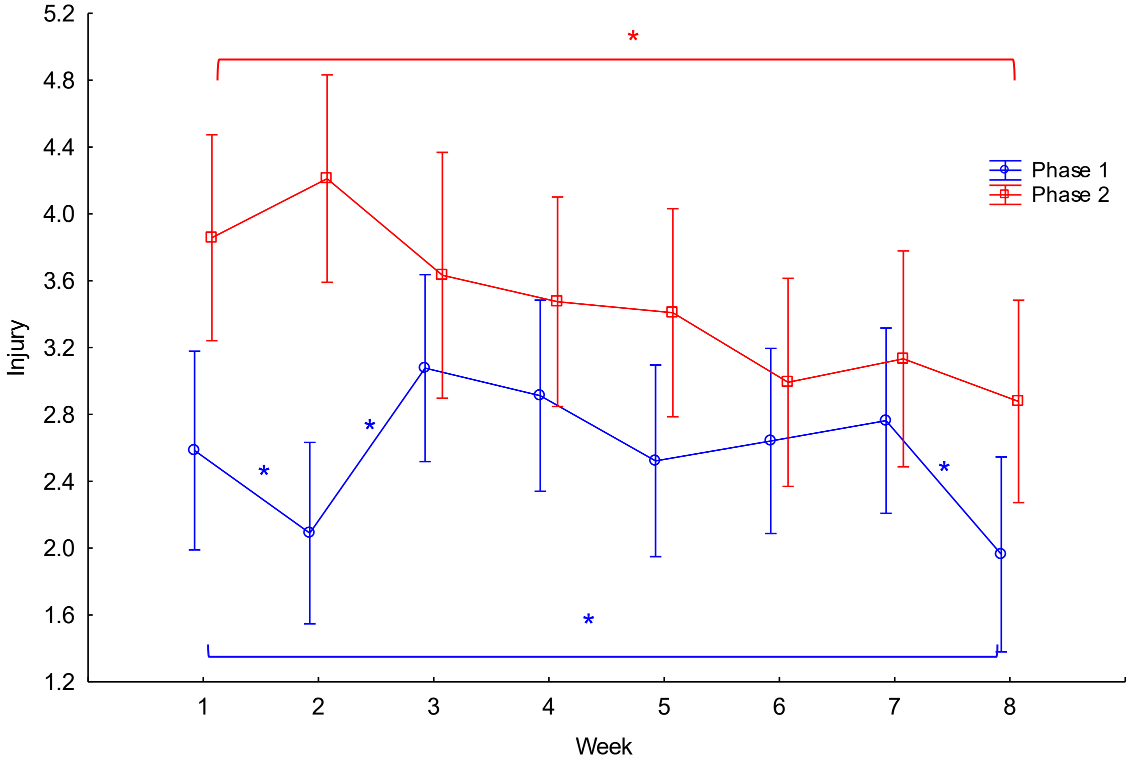
Comparison between Phase 1 and Phase 2

The total group (p<0.01), male and female dancers (p<0.01), and both levels (p<0.01) showed significantly higher EX scores during P2 compared to P1. The weekly scores for P1 and P2 were significantly different from each other (p<0.01), as illustrated in Figure 4.28. Both male dancers and female dancers (p=0.19), as well as the SP and PGA groups (p=0.13) did not differ significantly from each other in terms of EX phase averages over the two phases.

Injury (IN)

Phase 1

The total group reports showed significantly less injury (IN) at the end of P1 compared to the start of the phase (p=0.02). Significant fluctuations in weekly averages were noted, with less IN in week 2 (p=0.05), more in week 3 (p<0.01) and less again in week 8 (p<0.01). Figure 4.29 shows the weekly fluctuations of the total group. No significant difference was observed between IN P1 phase averages for male and female dancers (p=0.52), or for levels (p=0.67).



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.29 Injury of the total group for Phase 1 and Phase 2.

Phase 2

The total group reported significantly lower injury scores at the end of P2 compared to the start of the phase (p<0.01). From week 2 to week 8, the IN weekly average follows a continuous downward slope. Figure 4.28 shows the weekly fluctuations of the total group. No significant difference was observed between IN phase averages for male and female dancers (p=0.51), or for levels (p=0.52) in P2.

Comparison between Phase 1 and Phase 2

The total group, sex groups (male p=0.02; female p=0.01) and levels (PGA p=0.03; SP p<0.01) reported significantly higher IN scores during P2 compared to P1. For the total group, the weekly scores from P1 were significantly different from P2 (p<0.01), as can be observed in Figure 4.29. Neither male and female dancers (p=0.94), nor SP and PGA groups (p=0.83) differed significantly from each other in terms of IN phase averages over the two phases.

Being in Shape (IS)

Phase 1

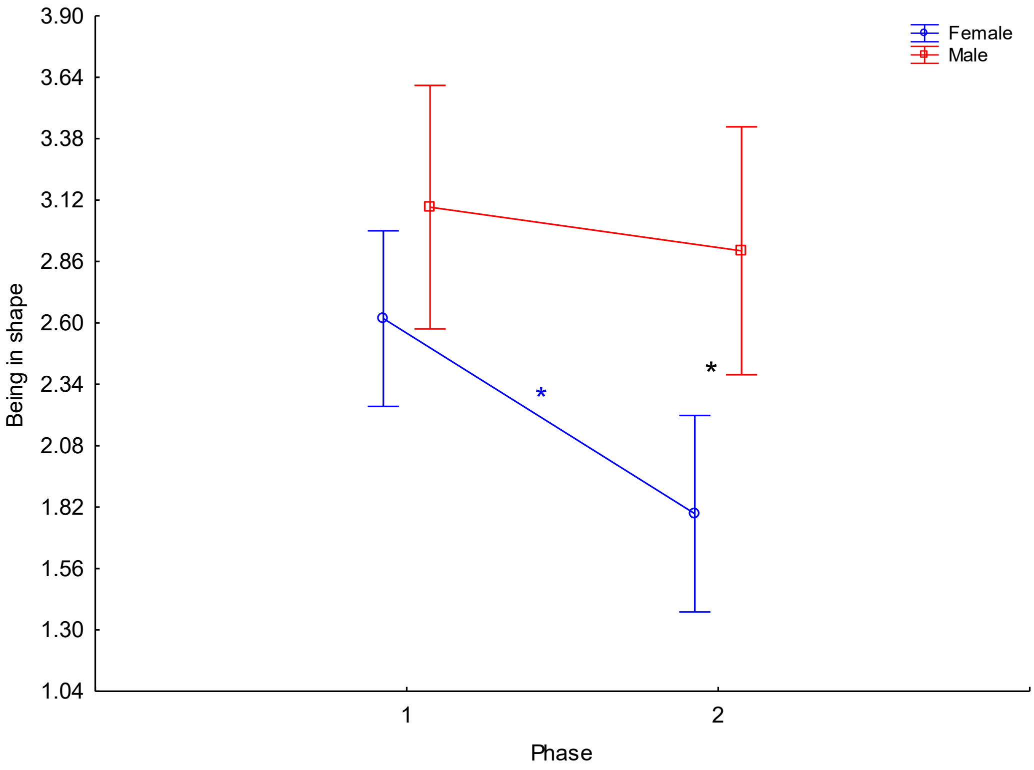
No significant difference in being in shape (IS) weekly averages for the total group was observed between the start and end points of P1 (p=0.55). A significant reduction was seen in week 3 (p=0.04), while and an increase occurred in week 8 (p=0.04). No significant difference was observed between IS phase averages for the sex groups (p=0.14), or for the levels (p=0.97) in P1.

Phase 2

Being in shape scores of the total group followed an upward trend during P2. However, the IS scores in week 8 were not significantly more than those in week 1 (p=0.20). Male dancers reported to feel significantly more IS compared to female dancers in P2 (p<0.01), as illustrated in Figure 4.30. No significant difference in P2 averages was seen between the levels (p=0.35).

Comparison between Phase 1 and Phase 2

The total group (p<0.01) and both levels (PGA p<0.01; SP 0.02) felt significantly more IS during P2 than in P1. For the total group, the weekly averages differed significantly between the two phases (p=0.05), while phase averages of the two levels did not differ significantly from each other (p=0.22). Being in shape scores differed significantly between sex groups over the two phases (p<0.01), as illustrated in Figure 4.30. Female dancers felt significantly less IS during P2 compared to P1 (p<0.01), while male dancers' IS scores remained relatively constant (p=0.30).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.30 Being in shape of male dancers and female dancers during Phase 1 and Phase 2.

Personal accomplishment (PA)

Phase 1

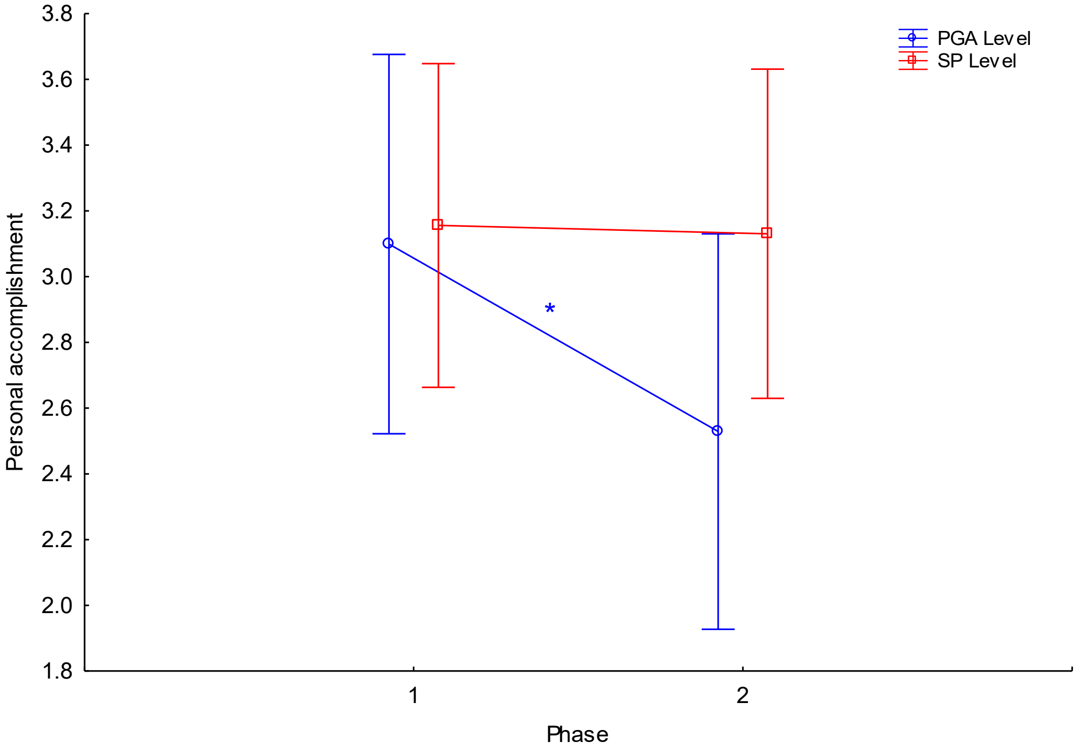
The total group reported significantly lower personal accomplishment (PA) scores at the end of the P1 compared to the start (p=0.04). In addition to this, the group's weekly average was significantly lower in week 3 than in the previous week (p=0.03). No significant difference in PA phase averages was seen within sex groups (p=0.46) or levels (p=0.88) during P1.

Phase 2

Similar PA weekly averages were noted for week 1 and week 8 for the total group (p=0.45), and no significant differences in phase averages were seen between sex groups (p=0.13) or levels (p=0.11).

Comparison between Phase 1 and Phase 2

The total group had lower PA scores in P2 compared to P1 (p=0.05), with the weekly averages differing significantly between the two phases (p<0.01). Despite no significant difference existing between phase averages of the sex groups (p=0.26), male dancers showed a similar PA phase average in P1 and P2 (p=0.56), while female dancers' scores decreased significantly from P1 to P2 (p=0.02). There was no significant difference between PA phase averages of the two levels, although a clear tendency towards significance was noted (p=0.07). The PGA group's phase average decreased from P1 to P2 (p=0.02), while the SP group's phase average remained constant (p=0.89). Figure 4.31 shows the difference between levels across the two phases.



Note: * indicates a significant difference between Phase 1 and Phase 2 of the PGA level (p≤0.05).

Figure 4.31 Personal accomplishment of PGA and SP groups for both Phase 1 and Phase 2.

Self-efficacy (S-E)

Phase 1

Self-efficacy (S-E) weekly averages of the total group stayed similar throughout P1, with no significant fluctuations and no significant difference in weekly averages between the beginning and end of P1 (p=0.68). While not significant, a clear tendency towards significance was seen when comparing the female dancers' lower S-E phase average with the male dancers' S-E average for P1 (p=0.06). No significant difference was found between the phase averages of the levels (p=0.58).

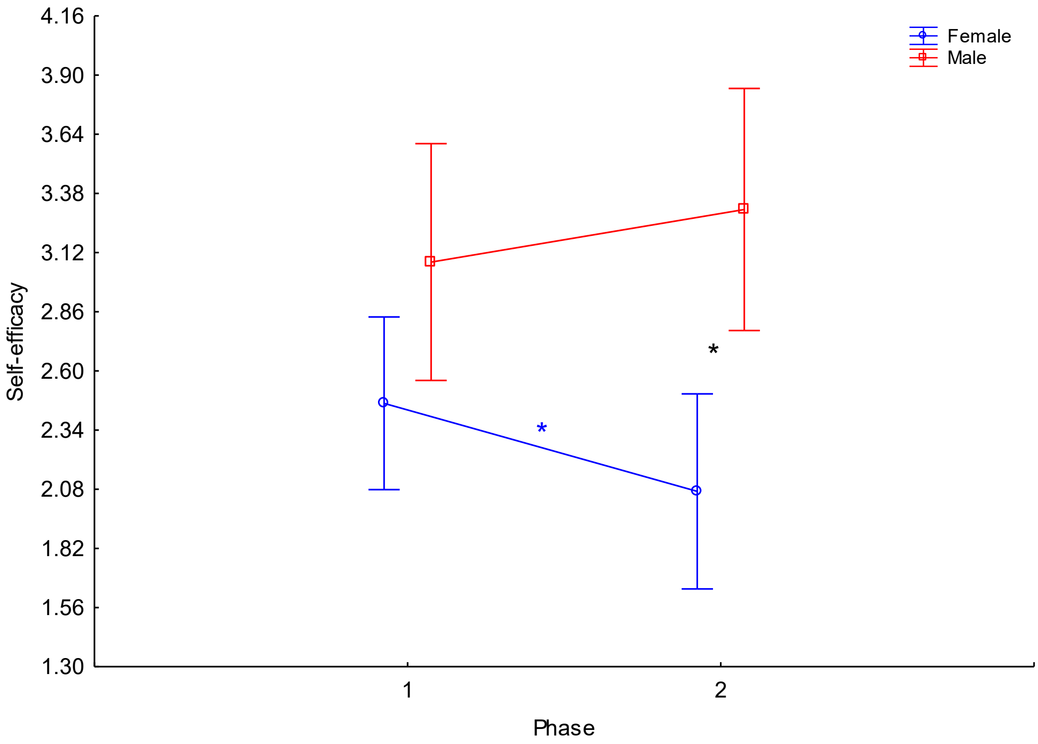
Phase 2

Weekly averages stayed relatively constant throughout P2, with no significant fluctuations besides a tendency towards a significant increase in week 7 (p=0.06). No significant difference in weekly averages was seen between week 1 and week 8 of P2 (p=0.98). During

P2, female dancers had a significantly lower S-E phase average than male dancers (p<0.01). No significant difference was found between the phase averages of the levels during P2 (p=0.66).

Comparison between Phase 1 and Phase 2

No significant difference in S-E phase averages between P1 and P2 was seen for the total group (p=0.55). In addition, the weekly averages were similar for the two phases (p=0.17). The two sex groups showed significantly different S-E phase averages for P1 and P2 (p=0.03). Male dancers showed no significant change between the two phases (p=0.26), while the female dancers' S-E phase average decreased significantly (p=0.03). The differences between the sex groups can be seen in Figure 4.32. The two levels had similar phase averages across P1 and P2 (p=0.24), and neither group showed significant changes in their phase averages. The PGA group's phase average did not decrease significantly (p=0.26), while the SP group's average did not increase significantly (p=0.63) from P1 to P2.



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05), * indicates a significant difference between male and female dancers in Phase 2.

Figure 4.32 Self-efficacy of male dancers and female dancers during Phase 1 and Phase 2.

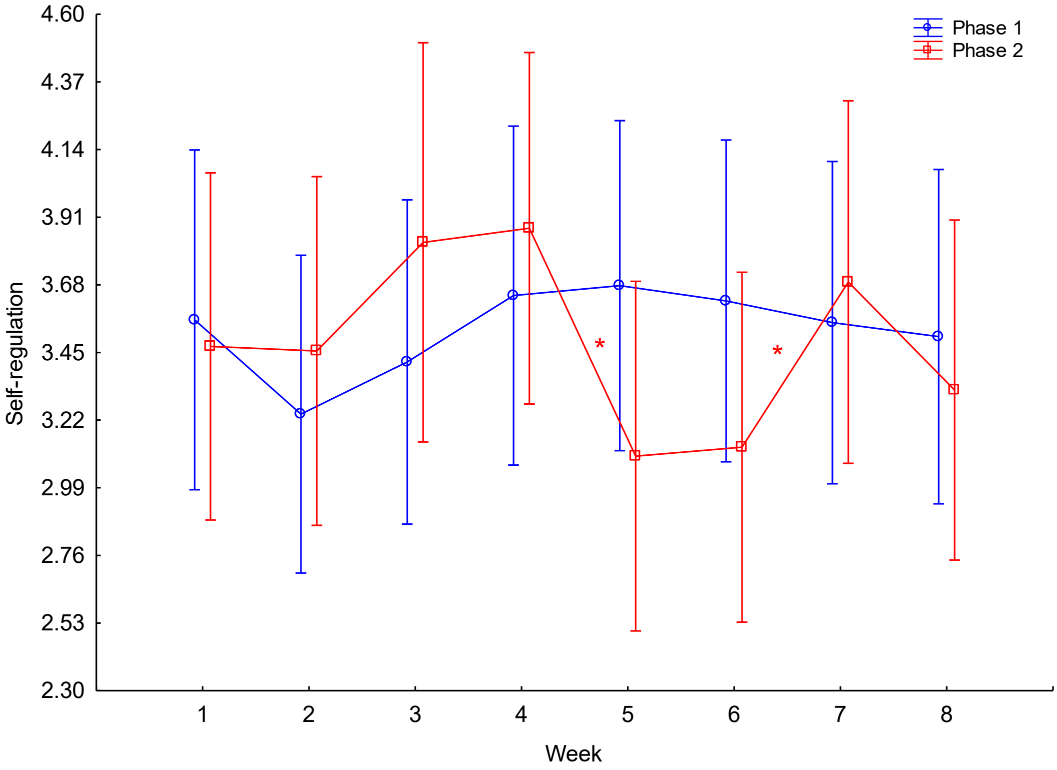
Self-regulation (S-R)

Phase 1

The self-regulation (S-R) weekly averages for the total group remained relatively constant throughout P1. There were neither significant fluctuations between weekly averages nor significant differences between the first and last week of P1 (p=0.81) (Figure 4.33). No significant difference between either male and female dancers (p=0.34), or between SP and PGA groups (p=0.51) were observed.

Phase 2

The weekly averages for S-R in the total group for the first and last week of P2 were similar to each other in P2 (p=0.53). Significantly lower S-R scores were noted in week 5 (p<0.01), followed by significantly higher S-R scores in week 7 (p=0.02). Comparative weekly scores for P1 and P2 can be seen in Figure 4.32. During P2, female dancers reported significantly lower S-R scores on average compared to male dancers (p=0.01). No significant difference in S-R phase averages was seen between the PGA and SP groups in P2 (p=0.23).

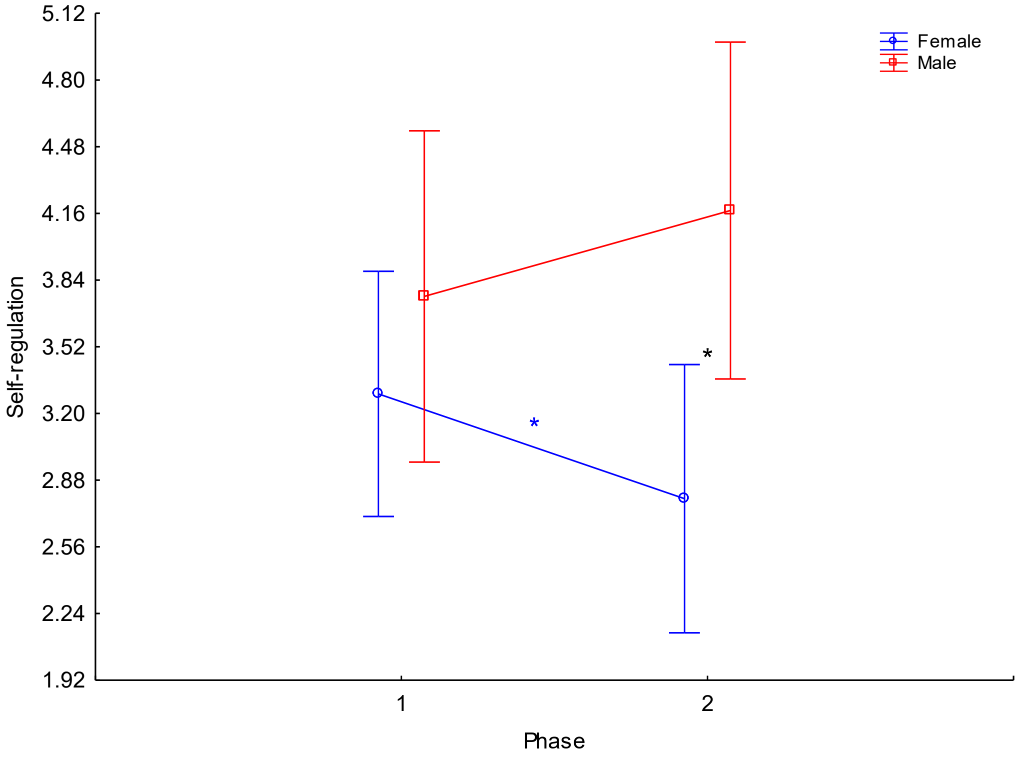


Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.33 Self-regulation of the total group for Phase 1 and Phase 2.

Comparison between Phase 1 and Phase 2

Despite the total group showing similar S-R phase averages for P1 and P2 (p=0.80), the weekly averages for the two phases differed significantly from each other (p=0.01). Differences between the two phases for the total group are depicted in Figure 4.34. The two sex groups had significantly different phase averages across the two phases (p=0.02), as illustrated in Figure 4.33. While the S-R phase average of female dancers decreased significantly from P1 to P2 (p=0.4), the P2 phase average scores for male dancers was not significant (p=0.14). The two levels had similar phase averages during the two phases (p=0.47) and no significant change in phase averages for either of the groups was seen between P1 and P2 (PGA p=0.53, SP p=0.70).



Note: * indicates a significant difference between Phase 1 and Phase 2 of the female dancers (p≤0.05),
* indicates a significant difference between male and female dancers in Phase 2.

Figure 4.34 Self-regulation of male dancers and female dancers during Phase 1 and Phase 2.

Summary of fluctuations in weekly averages

Table 4.4 offers a summary of all the significant weekly fluctuations in RESTQ subscales. The table provides a holistic overview of all the scales that increased or decreased in a specific week during each phase.

Table 4.4 Weekly significant fluctuations in RESTQ subscales for the total group during Phase 1 and Phase 2.

Stress subscales			Recovery subscales		
General stress	W2 W6	↑ ↓	**General recovery**	W3	↓
Sport specific stress	W2	↑	**Sport specific recovery**	W5	↓
	W6	↓	**Social stress**	W5 W8	↑ (p=0.6) ↑
General stress^	W6	↓	**Physical recovery**	W4 W5 W6 W8	↑ ↓ ↑ ↑
Emotional stress	W2 W3 W6	↑ ↓ ↓	**General well-being**	W3 W6	↓ ↑
Social stress	W5 W6	↑ ↓	**Sleep quality**	W3 W6 W8 W2	↓ ↓ ↑ (p=0.6) ↓ (consistently increase afterwards)
Conflict/pressure	W6 W7 W8	↓ ↑ ↓	**Being in shape**	W3 W8	↓ ↑
Fatigue	W2 W4 W6	↑ ↓ ↓	**Personal accomplishment**	W3	↓

	W7	↑			
Lack of energy	W2 W5 W6	↓ (p=0.6) ↑ ↓ (p=0.6)	**Self-efficacy**	W7	↑ (p=0.06)
Physical complaints	W3 W8 W2	↑ (p=0.6) ↓ ↑ (p=0.6)	**Self-regulation**	W5 (W6) W7	↓ Remained low ↑
Disturbed breaks	W2 W4 W5 W6	↑ ↓ ↑ (p=0.07) ↓			
Emotional exhaustion	W3 W4 W5 W8	↑ ↓ ↓ ↓ (p=0.08)			
Injury	W2 W3 W8	↓ ↑ ↓			

Note: Blue represents Phase 1, red represents Phase 2.

D. Internal training load

The sRPE training load (TL) of the two phases is shown in Table 4.5. It is important to note that weekly scores reported below do not represent the cumulative TL of each week, but rather the average daily TL per week of company training and performance days. Accordingly, the values in Table 4.5 do not reflect the number of days that dancers trained or rested during each week, but merely the TL experienced on training and performance days.

Table 4.5 **The average daily TL, per week, of ballet, team practice (class and rehearsal) and stage performance**

	Phase 1					Phase 2				
	All	Male	Female	SP	PGA	All	Male	Female	SP	PGA
Total ballet	808.56 ± 503.35	884.59 ± 626.99	777.59 ± 440.09	829.26 ± 540.15	780.25 ± 447.36	🟧 830.38 ± 543.52	🟧 1222.37 ± 636.54 *	🟩 725.93 ± 463.94 *	871.52 ± 552.37	🟩 737.83 ± 513.05
Team practise	774.36 ± 509.08	843.42 ± 634.67	746.80 ± 446.94	789.65 ± 452.29	753.55 ± 460.00	625.77 ± 550.54	925.23 ± 707.00 *	🟩 548.71 ± 474.02 *	633.32 ± 558.86	609.45 ± 533.79
Performance	433.49 ± 473.37	652.05 ± 579.98 *	344.44 ± 394.85 *	513.75 ± 536.86 *	323.13 ± 347.30 *	468.66 ± 360.38	786.83 ± 424.63 *	391.01 ± 296.06 *	526.08 ± 375.81 *	311.79 ± 258.11 *

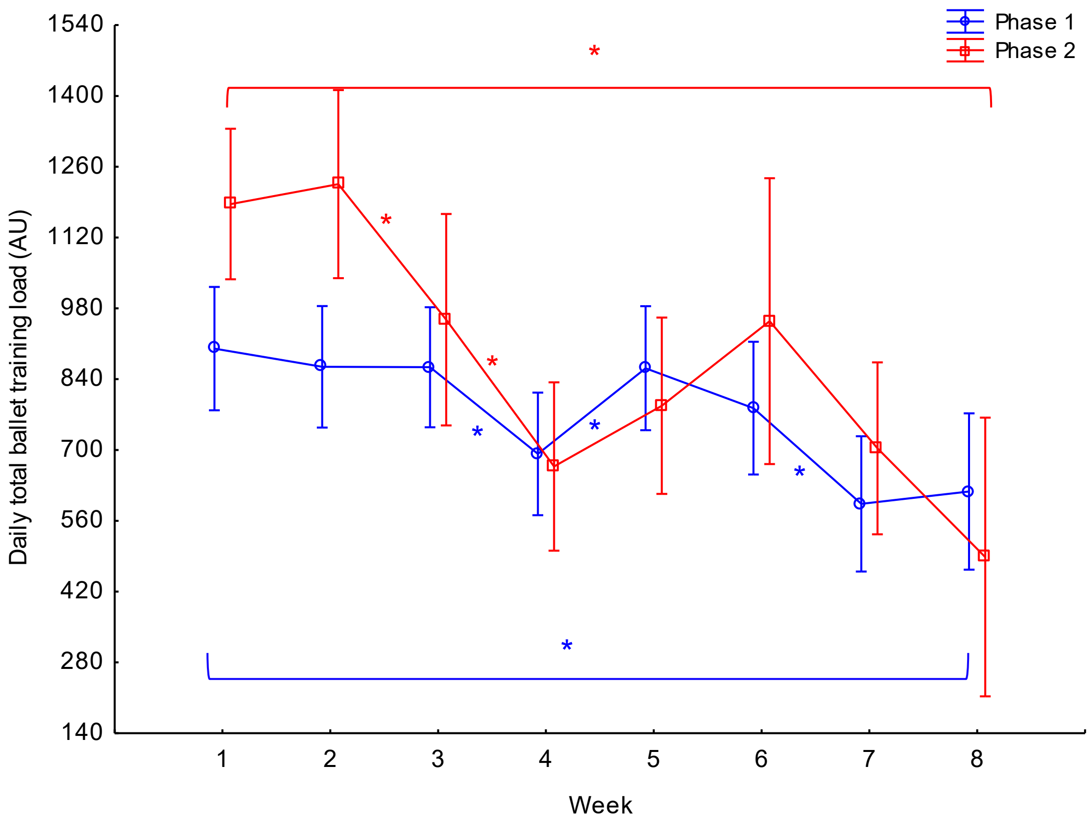
Total Ballet = all company activities (rehearsal and performance); Team practice = rehearsal and technique class; Performance = stage performances; All = total group of ballet dancers.

Note: p≤0.05 intra- or inter-phases; orange indicates a significant increase from P1 to P2, green indicates a significant decrease from P1 to P2. * indicates a significant inter-subgroup (between levels or between sex groups) difference within the particular phase.

Total ballet (TB)

Phase 1

Daily total ballet (TB) TL of the total group was significantly lower in week 8 compared to week 1 (p<0.01). The TB TL followed a gradual downward slope during P1, with the exception of a significant decrease in week 4 (p=0.01) and week 7 (p=0.01), and a significant increase in week 5 (p=0.01) (Figure 4.35). There was no significant difference in TL between male and female dancers (p=0.87), or between levels (p=0.08). Although not significant, SP dancers showed a higher TB TL than PGA dancers.



Note: * * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

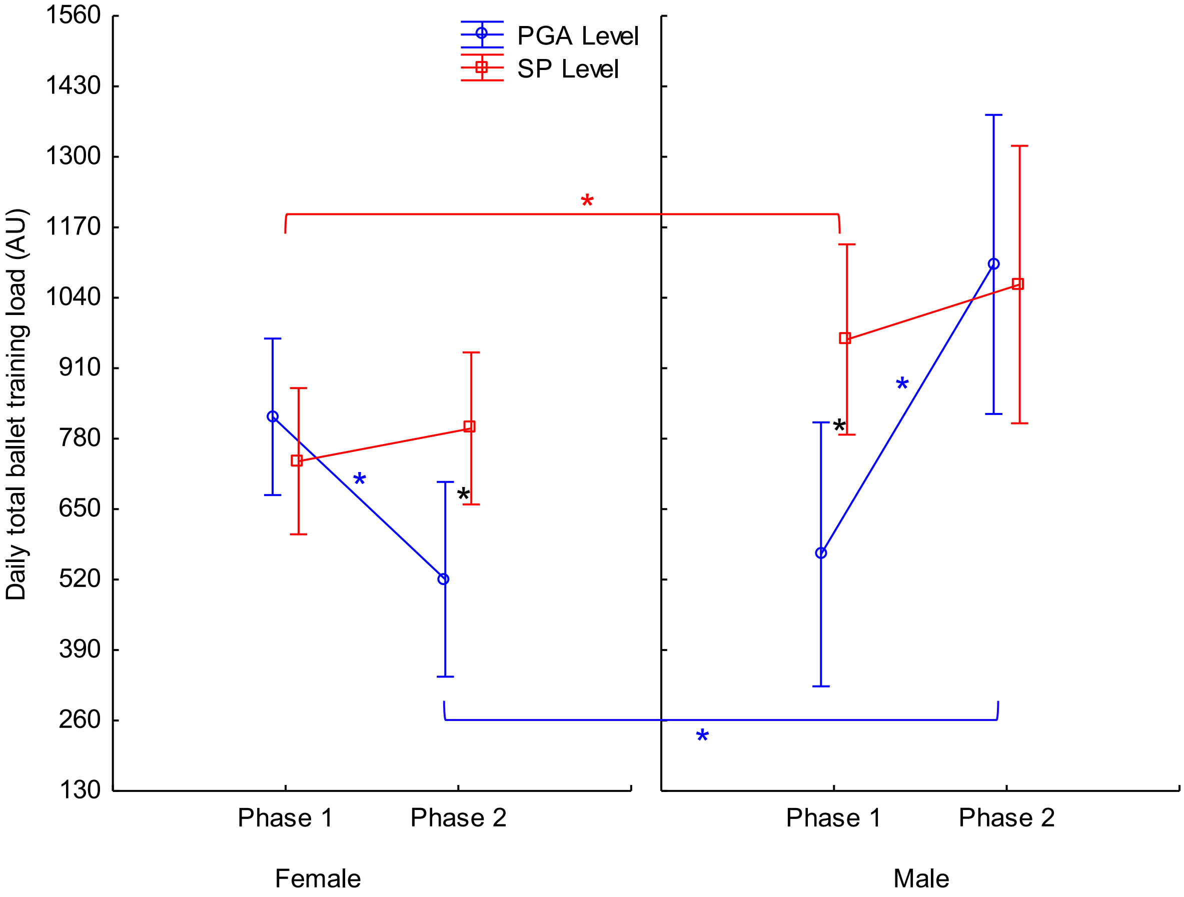
Figure 4.35 **Total ballet training load of the total group for Phase 1 and Phase 2.**

Phase 2

The TB TL for the total group was significantly lower (p<0.01) in week 8 compared to week 1 of P2. Significant weekly fluctuations occurred, with significant decreases in week 3 (p=0.04) and week 4 (p=0.02), as illustrated in Figure 4.35 above. Male dancers showed a significantly higher TL phase average than female dancers (p<0.01). The SP and PGA groups' daily TL did not differ significantly from each other during P2 (p=0.28).

Comparison between Phase 1 and Phase 2

For the total group, P2's average TB TL was significantly higher compared to that of P1 (p=0.01). In addition, the weekly scores between the two phases differed significantly from each other (p<0.01), as illustrated in Figure 4.35. The TB TL of female dancers was significantly lower in P2 compared to P1, while male dancers showed significantly higher average TB TL in P2 compared to P1. Daily TB TL phase averages differed significantly between sex groups over the two phases (p<0.01). In contrast, levels showed no significant difference in phase averages (p=0.65). However, the PGA group's TB TL decreased significantly from P1 to P2 (p=0.04), while the SP group's TB TL remained relatively constant (p=0.16). It is important to note that when comparisons of phase averages between sex-specific levels were made, male and female SP and PGA groups reported significantly different TB TL values from one another over the two phases (p<0.01). Figure 4.36 shows the inter- and intra-sex level differences of TB TL over P1 and P2. While the male-PGA group (m-PGA) increased (p<0.01) from P1 to P2, the female PGA (f-PGA) group decreased (p<0.01). The other two subgroups did not change significantly (female SP p=0.13; male SP p=0.35).



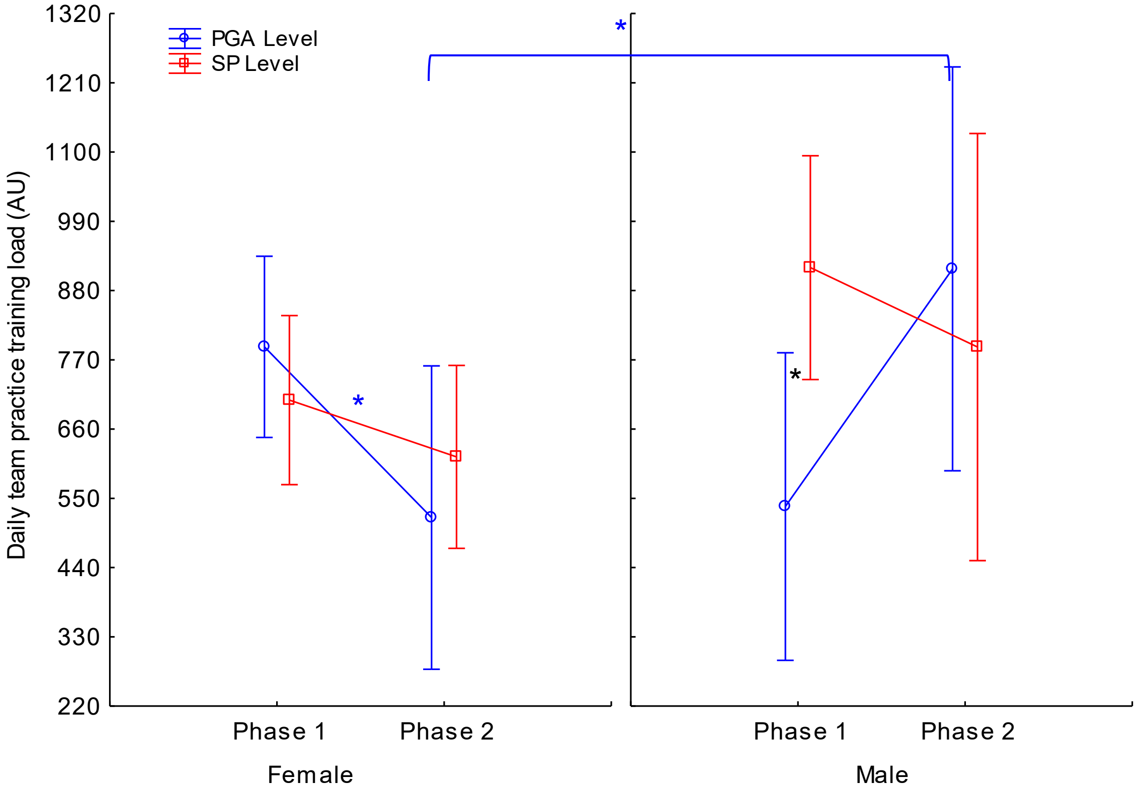
Note: * * indicates a significant difference between the two phases at the end points of the line, of the particular level (p≤0.05). * indicates a significant difference between the two levels' phase averages during the particular phase.

Figure 4.36 **Total ballet training Load of sex-specific levels groups during Phase 1 and Phase 2.**

Team practice (TP)

No significant difference was seen between the sex groups (p=0.81) or between the levels (p=0.10) in P1 for team practice (TP) TL. The average TP TL for male dancers during P2 was significantly higher than that of female dancers (p=0.04), but the phase average for the levels still showed no significant difference from each other (p=0.92) during P2. Comparing P1 and P2, the male dancers (p=0.35), PGA group (p=0.65) and SP group (p=0.30) showed no significant difference in TP TL. In contrast, the female dancers showed a significant decrease in TP TL from P1 to P2 (p=0.04).

Again, a significant difference between male and female SP and PGA groups was noted when sex-specific levels were compared over the two phases (p<0.04). The increase in the male dancer's group in P2 can be ascribed to an increase (p=0.06) in the m-PGA group. This is despite the slight decrease (p=0.50) in the male SP group's (m-SP) values. Female-PGA group decreased significantly from P1 to P2 (p=0.05). Figure 4.37 shows the inter- and intra-sex level differences of TP TL over P1 and P2.



Note: * indicates a significant difference between the two phases at the end points of the line, of the PGA group (p≤0.05). * indicates a significant difference between the two levels' phase averages during the particular phase.

Figure 4.27 Team practice training load of the total group for Phase 1 and Phase 2.

Performance

Both the sexes and the levels groups differed significantly from each other in both P1 and P2 for performance TL. The SP group had higher performance TL per day compared to the PGA group (P1 p=0.02; P2 p=0.04) and the male group had higher TL than the female group (P1 p=0.05; P2 p=0.04).

E. External training load

Impacts

The magnitude of the daily vertical impact for total group, sex groups and levels was investigated. Impact was measured in gravitational force equivalents (G-force).

No significant inter-sex (p=0.39) or inter-level (p=0.09) differences were found for the daily vertical impact total. In addition, no significant differences were seen between any of the four sub-groups (male-SP, m-PGA, female-SP, f-PGA) when intra-sex levels were investigated (p=0.93). No significant differences in daily impact load were found between any weeks for the total group.

Zone-categorised impacts

Impacts were categorised according to magnitude in the standard STATSport® (Ireland) zones, as illustrated in Figure 4.38. The peak of each impact was recorded. Impact incidences were required to be at least 3g in magnitude to be taken into account for analysis. Impact data was categorised and analysed as a whole for the total group. A significantly higher number of impacts occurred in Zone 1 (Z1) compared to Zone 2 (Z2) (p<0.01) and Zones 3 to 6 (p<0.01). Zone 2 was also significantly higher than Zones 3 to 6 (p<0.01).

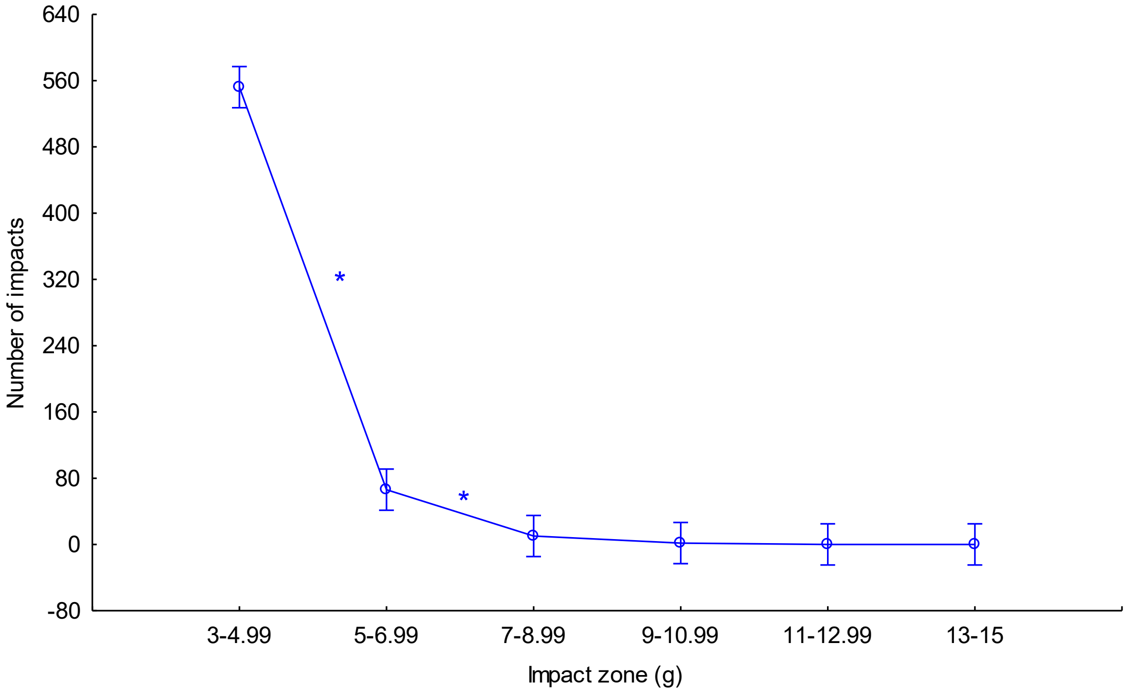


Figure 4.38 Impacts categorised in zones of magnitude for the total group.

F. Pain

Phase 1

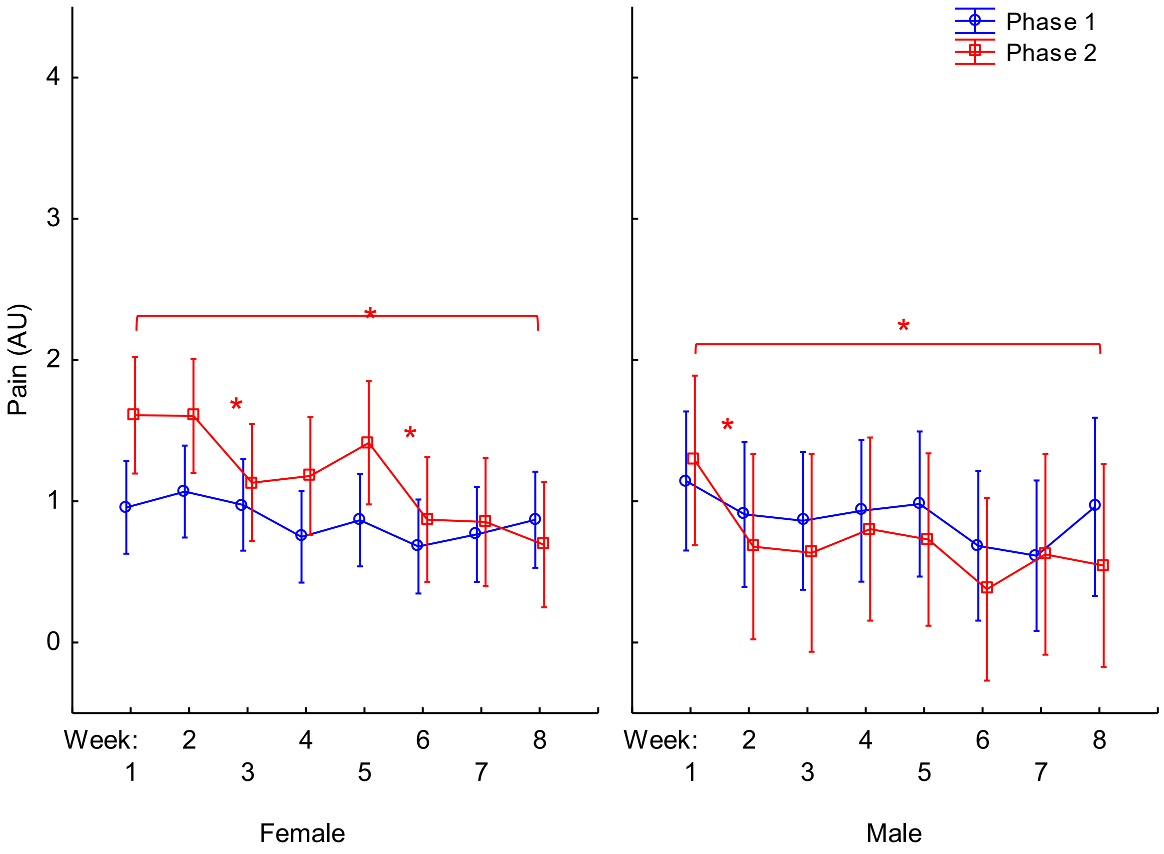
The weekly average pain of the total group remained relatively constant throughout P1. No significant weekly fluctuations and no significant difference between the start and end points of P1 (p=0.39) were seen. There were also no significant differences in pain phase averages between male and female dancers (p=0.94), or between levels (p=0.25).

Phase 2

During P2, the total group showed significantly lower pain scores at the end of the phase than at the start of the phase (p<0.01). A significant reduction in pain of the total group was seen in week 6 (p<0.01). No significant difference in pain phase averages was seen between male and female dancers (p=0.14) or between levels (p=0.10) in P2.

Comparison between Phase 1 and Phase 2

The pain scores of the total group did not differ significantly between P1 and P2 (p=0.66). However, the two phases showed significantly different weekly scores (p=0.02), as illustrated in Figure 4.39. No significant change occurred in the phase average from P1 to P2 for the sex groups (male p<0.46; female p<0.08) or levels (PGA p=0.83; SP p=0.32). Neither the sex groups (p=0.11) nor the levels (p=0.43) showed any significant difference from each other over the two phases.



Note: * indicates a significant difference between the two weeks at the end points of the line, in the particular phase (p≤0.05).

Figure 4.39 Weekly pain averages of male dancers and female dancers over Phase 1 and Phase 2 and the difference between the two groups (p=0.58).

G. Correlations

1. Recovery-stress states and the subsequent week's perceived pain

The four main RESTQ scales (GS, GR, SsS, SsR) were each correlated to the average perceived pain of the following week. Correlations were done for the total group, two sex groups and two levels groups. No single RESTQ scale was significantly correlated to perceived pain for all groups during both P1 and P2. Table 4.6 provides the correlation results.

Table 4.6 Correlations between RESTQ main scales and the subsequent week's perceived pain across all groups.

	Phase 1					Phase 2				
	All	**Male**	**Female**	**SP**	**PGA**	**All**	**Male**	**Female**	**SP**	**PGA**
GS : P	0.13 p=0.08	0.53 p<0.01 *	-0.07 p=0.46	0.14 p=0.17	0.18 p=0.14	0.48 p<0.01 **	0.85 p<0.01 **	0.37 p<0.01 **	0.53 p<0.01 **	0.39 p=0.04 *
SsS : P	0.18 p=0.02 *	0.44 p<0.01 **	0.02 p=0.86	0.19 p=0.05 *	0.16 P=0.16	0.50 p<0.01 **	0.77 p<0.01 **	0.44 p<0.01 **	0.51 p<0.01 **	0.58 p<0.01 **
GR : P	-0.17 p=0.03 *	-0.09 p=0.55	-0.22 p=0.01 **	-0.04 p=0.70	-0.35 p<0.01 **	-0.36 p<0.01 **	-0.56 p<0.01 **	-0.31 p<0.01 **	-0.46 p<0.01 **	-0.16 p=0.39
SsR : P	-0.18 p=0.02 *	0.12 p=0.45	-0.28 p<0.01 **	0.01 p=0.93	-0.40 p<0.01 **	-0.22 p=0.02 **	-0.10 p=0.61	-0.16 p<0.17	-0.19 p=0.10	-0.27 p=0.15

Note: **p ≤0.01; *p≤0.05; All = total group of dancers, P = pain

Phase 1

For the total group, SsS correlated significant positively, while GR and SsR had a significantly negative correlation with pain during P1 (weak correlation). For male dancers, both stress scales correlated significant positively to pain in P1 (moderate to strong correlation). In contrast, both recovery scales had significant negative correlations with pain reported by female dancers and the PGA group (weak correlations). The SP group showed a significant positive correlation only between SsS and pain in P1 (weak correlation).

Phase 2

During P2, high stress scores (GS and SsS) significantly correlated with pain for all participation groups (total group, both sex groups, both levels) (moderate-strong correlations). Low GR significantly correlated with pain of all the participation groups except for the PGA group (moderate-strong correlations). In addition to the scales mentioned above, the total group's pain also correlated significant negatively with SsR (weak correlation).

2. Recovery-stress states and preceding week's internal training load

The group's average daily TL (sRPE training load) over a week was correlated to the RESTQ reports completed in the first half of the following week. The RESTQ form completed by participants in week 1 could therefore not be used. Only the four main RESTQ scales were compared to training load. Table 4.7 provides the Pearson correlations for sex groups and levels during each phase.

Table 4.7 Correlation between RESTQ main scales and the previous week's daily cumulative training load, averaged over a week.

	Phase 1					Phase 2				
	All	**Male**	**Female**	**SP**	**PGA**	**All**	**Male**	**Female**	**SP**	**PGA**
GS : TL	0.02 p=0.77	-0.13 p=0.39	0.13 p=0.20	0.02 p=0.85	0.03 p=0.81	-0.05 p=0.61	0.10 p=0.63	-0.05 p=0.67	0.15 p=0.23	-0.40 p=0.05 *
SsS : TL	0.04 p=0.59	-0.13 p=0.42	0.17 p=0.08	0.02 p=0.85	0.11 p=0.36	0.14 p=0.19	0.36 p=0.08	0.07 p=0.59	0.31 p=0.01 **	-0.20 p=0.33
GR : TL	-0.13 p=0.12	-0.32 p=0.03 *	-0.01 p=0.95	-0.08 p=0.46	-0.20 p=0.11	0.08 p=0.46	-0.02 p=0.91	0.10 p=0.41	-0.07 p=0.56	0.36 p=0.07

SsR : TL	0.01 p=0.91	-0.42 p<0.01 **	0.22 p=0.02 *	0.00 p=0.97	0.01 p=0.94	0.38 p<0.01 **	0.41 p=0.05 *	0.26 p=0.03 *	0.39 p<0.01 **	0.38 p=0.06
TS : TL	0.04 p=0.62	-0.14 p=0.38	0.17 p=0.09	0.03 p=0.79	0.10 p=0.45	0.05 p=0.66	0.26 p=0.22	-0.01 p=0.97	0.25 p=0.05 *	-0.30 p=0.15
TR : TL	-0.06 p=0.47	-0.42 p<0.01 **	0.12 p=0.20	-0.02 p=0.88	-0.12 p=0.37	0.25 p=0.02 *	0.18 p=0.39	0.19 p=0.13	0.17 p=0.17	0.38 p=0.05 *

**p ≤0.01; *p≤0.05

Phase 1

During P1, the total group had no significant correlations between any of the main RESTQ scales and daily training load. Male dancers' training load had a significant moderate negative correlation with all recovery scales (GR, SsR, TR), while female dancers showed a significant weak positive correlation with SsR. No significant correlations were found for any of the two levels during P1.

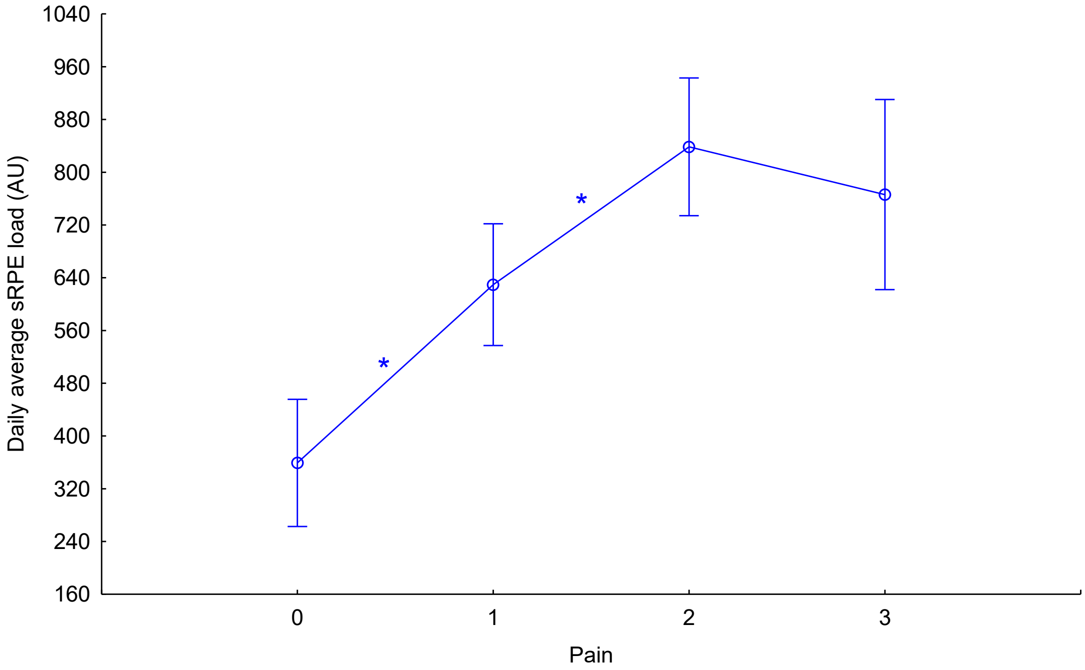
Phase 2

Both male and female dancers had a significant correlation only between high TL and high SsR in P2 (weak-moderate correlations). In consensus, training load of the SP group correlated positively with SsR, as well as SsS and TS (moderate correlations). The total group and PGA group's training load showed a significant positive correlation with TR (weak-moderate correlation). The PGA group was the only group that showed a significant negative correlation between training load and a stress scale (GS)(moderate correlation).

3. Subjective training load and pain

Pain was compared to the total daily training load. All activities reported on the online application, including company dance activities (class, rehearsal and performance) as well as additional exercise, were included in this analysis. As pain scores did not differ significantly over the duration of data collection, phases were not taken into consideration when correlations for levels and sex groups were investigated.

All participation groups showed a significant ($p<0.01$) weak positive correlation between daily perceived pain and training load (total group r=0.21; male dancers r=0.17; female dancers r=0.23; SP r=0.23; PGA r=0.18). For the full duration of data collection, the total group's daily training load showed a positive correlation with pain levels 0–2, and a negative correlation with pain level 3. Correlations are depicted in Figure 4.40.



Note: * indicates a significant difference between the two consecutive pain levels ($p \leq 0.05$).

Figure 4.40 Correlation between daily training load of all activities reported and perceived pain of the total group.

4. Internal and external training load

The total vertical impacts were compared to the internal training load of the same session. There were 201 cases included in the calculation. A weak positive correlation was found between the specific subjective and objective training load variables (Rmcorr=0.25; $p<0.01$).

Chapter Five

DISCUSSION AND CONCLUSION

A. Introduction

The purpose of this chapter is to give an overview of the results and discuss the main research findings with regard to the research questions listed in Chapter One. Furthermore, general conclusions based on the findings, together with limitations of the current study and recommendations for future studies are presented.

Published research involving professional ballet dancers is currently limited in relation to certain topics focused on in this study. It is therefore inevitable that references to sport codes might dominate some of the sections. Literature shows that professional ballet dancers are at high risk for injuries and for developing overtraining syndrome due to aspects specifically related to the ballet culture and training regimes they are exposed to in highly competitive company environments. High dance training loads, inferior cardiovascular capacities compared to other power-endurance athletes (Sanders et al., 2019), irregular sleep schedules during performance season (Fietze et al., 2009), great pressure to maintain low body fat percentage (Micheli et al., 2005), extreme flexibility and joint range of motion (Koutedakis & Jamurtas, 2004), and the ‘show must go on’ mind-set that commonly causes dancers to dance with the presence of musculoskeletal pain (Harrison & Ruddock-Hudson, 2017).

Previous research suggests that a primary issue could be the lack of proper, holistic recovery. Dancers are not educated on the correct recovery strategies. Instead, they are encouraged to train harder and longer to reach better levels of dance technique from a young age. Many studies have researched injury risk factors in dancers, but limited research has been carried out on ballet impact load, recovery-stress states and the relationship of these factors with injury.

Consequently, the first four aims of this study were to investigate the recovery stress states, examine the internal and external training loads on dancers, and evaluate the pain experienced by professional ballet dancers over different phases of a ballet season. The fifth aim was to investigate significant correlations between the above mentioned four aims. To address these aims, pain, recovery-stress states and training load (subjective and objective) were assessed with the focus on inter-phase, inter-sex and inter-level differences. The following sections elaborate on the main findings after the 16-weeks (two eight-week phases) as they relate to the respective objectives.

B. Participants

Male dancers weighed more and were taller than female dancers in general. In contrast to Micheli et al. (2005), who reported a significant reduction in both body mass and body fat percentage over the nine-month season, female dancers' body mass did not change significantly from the start to the end of year. It should be noted that the current study only measured body mass. As a result, it could be the case that dancers' body composition (ratio between body fat percentage and muscle mass) changed over the period of the current study, but is not reflected in their body mass scores. One of the reasons for the lack of significant decrease in body weight in female dancers, could be the lower amount of performances during the year compared to Micheli et al. (2005) (seven to 10 performances per week for 13 weeks during the nine months, and approximately 50 performances in five consecutive weeks during their busiest season). Both Micheli et al. (2005) and the current study measured professional ballet dancers over a period of nearly nine months. In consensus with Micheli et al. (2005), male dancers showed no significant change in body mass over the year.

Both male and female dancers from the current study, had higher body mass averages at all time points compared to Micheli et al. (2005) (male preseason 71 ± 6.4kg; female preseason 51.6 ± 4.6). South Africa has a large variety of different ethnic groups with differences in body type. As a result, the current study's dancers fall into a variety of different ethnic groups, which could influence the average body mass of dancers in the company. Rush et al. (2007) stated that the ratio between body mass and body fat percentage differ between ethnic groups, and that visceral fat and muscularity may play a role therein. Bronner et al. (2014), however, reported demographics of seven professional ballet companies that showed that the body mass and height of dancers of both sexes from the current study were within the ranges of the reported companies. It was also noted that female dancers were more the same weight with smaller standard deviations compared to male dancers, whose weight covered a much larger range.

The larger range in male dancers' weight was confirmed by Bronner et al. (2014), who reported the average weight in seven professional ballet companies for male dancers ranged between 60.9–75.1kg with an standard deviation up to 17.6kg, while female dancers' average weight only ranged between 50.5–54.0kg with a standard deviation up to 7.7kg. The results might be evident of the high pressure female dancers are subjected to in relation to thinness (Liederbach & Compagno, 2001a; Micheli et al., 2005; Wilmerding et al. 2005).

Male dancers reported having danced professionally for longer than female dancers and were spread across a larger age range. This is in accordance with Micheli et al. (2005), who reported the age range of professional female ballet dancers to be 17 to 32 years (mean: 22 ± 3.8 years) and male dancers to be 18 to 38 years (mean: 24 ± 5.5 years). Bronner et al. (2014), however, reported mixed results on which sex had the highest number of professional experience in years among seven professional ballet companies.

The following sections summarise and discuss the findings as set out by the research aims and objectives in Chapter One.

C. Recovery-stress states

In the following section on recovery stress states, the specific objectives and hypotheses will be mentioned first. A discussion of the main findings in the order of differences between phases, sexes and levels of performance, will follow. Results in the current study indicated differences in various subscales. Due to the comprehensiveness of the RESTQ-76 Sport (RESTQ), not every separate scale and subscale will be discussed. The discussion that follows will emphasise the main findings and its implications. Please note that reference to the RESTQ-76 Sport will be abbreviated to RESTQ for the purpose of the discussion.

1.4 Recovery-stress states of dancers during the Rehearsal and Performance Phases

It was hypothesised that the professional ballet dancers will show significantly higher recovery scores and lower stress scores during the Rehearsal Phase (P1) compared to the Performance Phase (P2). The hypothesis was accepted. The total group had less total recovery (TR), sport-specific recovery (SsR) and general recovery (GR), and more total stress (TS), sport-specific stress (SsS) and general stress (GS) during P2 than during P1.

1.5 Recovery-stress states of male and female dancers

It was hypothesised that female dancers will have significantly higher stress scores than male dancers throughout the year. The hypothesis was rejected. No significant difference between male and female dancers' stress scores was found in either phases.

1.6 Recovery-stress states of dancers of different performance levels

It was hypothesised that lower-level dancers (PGA) will show significantly more recovery and less stress than higher-level dancers (SP) throughout the year. The hypothesis was rejected. No significant difference existed between SP and PGA groups' total stress or total recovery scores in either phase.

The first main finding of recovery-stress states was the significant effect specific training phases within a ballet season have on stress and recovery scales. Stress significantly increased and recovery significantly decreased for the total group from P1 to P2. The increase in stress and decrease in recovery may be due to the accumulation of stressors caused by the time of season (at the end of the year), the addition of performance stress, increased training load for the total group (as shown in the results), and changes in company management shortly before P2.

Changes in stress and recovery levels during specific training phases of a season have previously been reported in various sport codes, for example, swimming (Nagle et al., 2015; Nicolas et al., 2019; González-Boto et al., 2008; Zanini et al., 2018), rugby (Hartwig et al. 2009) and football (Faude et al., 2011). The current study showed a similar tendency to a group of male and female swimmers monitored by Zanini et al. (2018) from the start of the competition preparation to the end of competition season. As time progressed, the total group of swimmers showed an increase in general stress indexes between certain data collection points (points 2–3) and a significant decrease in general and sport-specific recovery scores from start to finish (points 1–4). In contrast with the latter study, Codonhato et al. (2018) reported that professional rhythmic gymnasts' recovery-stress states showed no significant difference throughout the year. A possible explanation could be that RESTQ reports were only collected four times during the season and each time was one week before a competition. If all competitions were evenly important and on the same level, this could explain the unchanged RESTQ scores.

For the total group, all stress subscales, except for lack of energy, increased from P1 to P2. Besides success, self-efficacy and self-regulation, which showed no significant change, the recovery subscales decreased. The findings on these subscales are simply mentioned here and will be discussed later, together with the specific changes that occurred in relation to them. To the researcher's knowledge, no study has been published on ballet dancers which investigated the changes in recovery-stress states over different training phases of a season.

The choreography of each production places unique physical and physiological demands on the dancers (Allen et al., 2012). Professional ballet dancers are expected to be performance ready in terms of both physical and technical aspects at any point in time throughout the year (Wyon & Redding, 2005). Although companies usually have one major performance season towards the end of the ballet season, additional performance weeks are spread throughout the year (Fietze et al., 2009). Diverse productions are performed at different times of the year (short performance seasons). Some are popular classical ballets that many of the company dancers have performed in previously, while other productions are new.

Performance seasons differ in duration, and the number of different productions and performances. A rehearsal period takes place prior to and often during a performance season. During this time, choreography is learnt and perfected. Consequently, training and performance phases throughout a ballet seasons are vastly different from traditional sport codes. However, changes in recovery-stress states between the eight-week P1 and P2 of the current study correlated to some extent with specific training periodisation phases of expert swimmers (Nicolas et al., 2019). Dancers' P1 correlated with the swimmers' moderate training phase (MP), while P2 correlated to an overload phase (OP) in swimmers. The MP measurement was taken after one week of moderate training and the OP measurement was taken after three weeks of increased training load with the goal of improving fitness. The RESTQ scales that changed significantly between the two phases (MP and OP) in this study were all replicated in the current study's results. Nicolas et al. (2019) used the RESTQ 36-R-Sport questionnaire and reported a decrease in total recovery, sport-specific recovery and being in shape. Scales that significantly increased were total stress, sport specific stress, general stress, fatigue, injury and emotional exhaustion. The fact that dancers' performance phase reflect the same characteristics as a sport overload phase shows dancers are not optimally prepared to perform during this phase, but instead show increased stress and decreased recovery associated with an training phase incorporated into sport training to enhance fitness prior to competition season.

Wyon and Redding (2005) reported that aerobic capacity of contemporary dancers improved after their performance season, but not after a rehearsal period. This supports the correlation between the overload phase of swimmers and the P2 of the current study that indicates P2 was at a higher training load than P1. Training load reports of the current study also confirmed increased training load in P2 for the total group.

The decrease in specific RESTQ subscales from P1 to P2 was supported by Di Fronso et al. (2013), who monitored amateur basketball players after both pre-competition and competition phases. RESTQ scores were collected after 21 days of training for the preseason phase and at the end of the season during the play-off phase for the competition phase results. The significant increase in emotional stress coincided with the current study's results, but the decrease in fatigue scores were in contrast with the current study's results for the total group. This dissimilarity might be due to the consistency in dancers' year-round training schedules and the fact that they do not have an overload phase shortly before performance season, as commonly seen in sport codes. Additionally, the current study's P1 was monitored at the beginning of the year and P2 was measured only at the end of the year, with many months intervening the two phases. In contrast to this, Di Fronso et al. (2013) and other studies cited previously in this section (Nicolas et al., 2019; Wyon & Redding, 2005; Zanini et al. 2018) monitored the preparation phases directly prior to competition phase.

When the current study's results of specific subscales during the two phases were compared to that of professional football players, dancers seemed to have lower recovery scores. Similarly, Faude et al. (2011) reported the accumulation of stress and lack of recovery towards the end of a competition period. Results showed that group averages for all stress subscales were between two and three in season, while averages for the recovery subscales were approximately four. In scores reported during P1 of the current study, it was evident that stress subscale scores were also mostly between two and three. In P2, on the other hand, the scores were closer to three as opposed to four. This might suggest that dancers recover less during a performance phase compared to football players during a competition phase and thus have a higher risk for developing overtraining syndrome. However, female dancers showed significantly lower recovery scores compared to male dancers during this phase. This suggests that male dancers' recovery might be more similar to male football players and that it is speculated that only female dancers who are at an increased risk for overtraining.

The second main finding in the recovery-stress states was that the most significant differences in RESTQ scores within certain phases could be attributed to sex specificity. During P2, sex specificity could specifically be seen in the recovery scales. All subscales that differed significantly between male and female dancers during P2 were as a result of a significant decrease in recovery scores of female dancers from P1 to P2, and not due to any significant changes in male dancers' scores. Only one recovery scale, sleep quality, decreased in male dancers from P1 to P2, while all recovery scales decreased significantly for female dancers.

Kellmann et al. (2001) stated that female athletes might experience stress responses to similar training loads differently than males. Di Fronso et al. (2013) continued by explaining that chronic increase in internal training loads may lead to poorer recovery and consequently lower self-efficacy. Additional stress, specific to P2, in conjunction with elevated responses to training load might have caused a similar effect in females as described by Di Fronso et al. (2013). Thus, even though training load did not increase in P2 for female dancers, heightened stress circumstances such as performance stress and change of company management before the start of P2, could have contributed to the lower physical recovery and self-efficacy scores of females compared to males during P2.

Low self-efficacy in female athletes has also been reported by Di Fronso et al. (2013) in basketball players. Otter et al. (2015) found self-efficacy was positively correlated to various performance measurements in female athletes. This increased the concern over the lower scores in female dancers. This is especially so, because the decrease is seen during P2 and is evidently a critical aspect of the season. Furthermore, the subscales of success, self-efficacy, being in shape and general well-being were all significantly lower for female dancers in P2 compared to P1. These scales were also significantly lower than male dancers during P2. This may indicate that female dancers are much harder on themselves than male dancers, causing them to feel less successful, less prepared, and less content during P2 specifically.

Edmonds et al. (2018) reported an increase in self-efficacy scores after the first (of two) performances compared to measurements taken one week prior in student dancers. The increased SE scores maintained the higher level until after the second and final performance. Although it may be true that the current study's female dancers' scores increased after the first performance, it was still lower than male dancers' for the entire eight-week phase.

Supporting the finding that sex-specificity was evident in RESTQ scores and not level-specificity, only three subscales showed differences between intra-sex levels of performance. The three scales were: emotional stress (ES), social stress (SS) and physical recovery (PR). In each subscale, male-PGA and female-PGA differed significantly from each other during P2, with female-PGA showing higher stress and lower recovery than male-

PGA. In contrast, the SP gender groups were relatively similar over the two phases. This might indicate that where intra-sex levels were significantly different, it is predominantly due to differences between the sex groups in the lower-level dancers as opposed to differences between sex groups in the higher-level dancers. Out of 21 subscales, only three showed significant intra-sex differences between levels. It is, therefore, unlikely that three sub-scales, of which only two were recovery scales, could have influenced the total recovery score for the female group as a whole. Thus, it is re-emphasised that possibly the biggest difference, subsequent to phase-specificity, was mediated by differences between male and female dancers.

No significant difference appeared between the SP and PGA group in any of the subscales. However, certain scales showed a significant change in either the SP or the PGA group from P1 to P2, while the other group showed no significant change. The scales that showed significant changes in the SP group were conflicts/pressure and fatigue (increased scores), general well-being and lack of energy (decreased scores). Scales that depicted significant changes in the PGA group were social recovery, sleep quality and personal accomplishment (decreased scores).

While ballet dancers showed no significant difference between levels while working together, other open- and closed-skill sports have reported differences in coping strategies with increased training load and high performance pressure (Calmeiro et al., 2014; Hartwig et al., 2009). More elite, higher-load adolescent males taking part in rugby showed better psychological recovery-stress profiles compared to lower-level players at lower training loads (Hartwig et al. 2009). Calmeiro et al. (2014) reported elite trap shooters showed better coping strategies to deal with negative appraisals than non-elite athletes during important competition moments.

Even though the SP and PGA group's scores did not differ significantly from each other, the higher-level (SP) dancers reported significantly more conflicts/pressure during P2 compared to P1. The lower-level (PGA) dancers, on the other hand, reported no significant change in conflicts/pressure levels. Filho et al. (2015) stated that it is not negative for elite athletes to have increased conflicts/pressure during performance, as it has shown to be positively correlated to performance. Professional cyclists has shown a positive correlation between conflicts/pressure scores and performance outcomes in the final phase of a multi-day stage race (Filho et al., 2015). This might relate to the end of a performance season or each time dancers perform on stage, since each performance is as important as any other in a dancer's case. Additional scales that have been reported to relate to performance include: being in shape, self-regulation, physical recovery, injury and general well-being. All of these scales showed negative scores in P2 for female dancers.

According to the RESTQ results, female dancers and the SP group are at high risk of developing overtraining syndrome at the end of a ballet season. It has been shown that RESTQ subscales are indicative of and sensitive to overreaching (Brink et al., 2012). The authors reported a low total recovery score two months before overreaching diagnosis when compared to healthy athletes' scores and scores taken for baseline data at the beginning of a season. Specific subscales that were sensitive were: emotional stress, physical recovery, general well-being, sleep quality, fatigue and being in shape. The last two mentioned scales showed the largest changes within the overreaching athletes in the mentioned study. Most of the mentioned scales showed negative changes in P2 for the female group and SP group.

Brink et al. (2012) suggested that overreaching can be identified in its early stages by monitoring athletes on a continuous basis. Negative changes in all six subscales mentioned by Brink et al. (2012) were noticed in female dancers in P2, compared to only three in male dancers in the same phase. The SP group showed changes in all six compared to the PGA group, which only showed changes in four of these subscales. The RESTQ results might suggest that female dancers are at a much greater risk of developing overtraining syndrome compared to the male dancers, and higher-level compared to the lower-level dancer. Extra care and attention should be given to these populations to reduce their risk and prevent overtraining. Walker and Nordin-Bates (2010) suggested that dancers are less anxious when they feel they are in control. A good strategy to lower anxiety and stress levels might therefore be to make dancers feel in control, specifically during high-pressure and demanding phases. This could be achieved by ensuring enough rehearsal time with constructive feedback on difficult steps, together with optimal physical, mental and emotional status of dancers.

D. Correlation between recovery-stress states and pain

It was hypothesised that pain scores would significantly correlate with high stress scores and low recovery scores for all groups during both phases. The hypothesis was rejected, as pain did not correlate with all scales for all groups across both phases.

Different scales correlated with each group in a unique way across the two phases. The three scales that needs to be highlighted are high sport-specific stress and low general recovery and sport specific recovery, which ranged between weak and strong correlations with pain for the total group across both phases.

Van der Does et al. (2017) supported the negative correlation between recovery scales and injury. The authors reported a significant correlation between decreased general recovery prior to acute injury and decreased sport-specific recovery prior overuse injury in sub-elite (basketball, volleyball and korfball) athletes. In contrast to the findings of the current study and others that will be discussed below, Van der Does et al. (2017) reported that perceived stress scales did not correlate with injury occurrence. The authors concluded that recovery seems to be more important in injury risk management than stress. A possible reason for the contradicting findings with the current study could be due to their methodology. Van der Does et al. (2017) collected only RESTQ data every three weeks and correlated that with reported injuries. Furthermore, the level of the basketball players (sub-elite) could also have an influence on the correlation.

As mentioned previously, female dancers reported significantly lower recovery scores in P2 compared to P1. Female recovery scores in P2 were also lower than male dancers' scores. While both male and female's stress scores increased significantly. According to the findings of Van der Does et al. (2017), the difference in recovery states might explain the non-significant, higher pain scores reported by female dancers compared to male dancers in P2.

The current study determined correlations between pain and the main RESTQ scales. However, only a few studies could be found that reported the correlation between injury and only specific subscales with either the RESTQ-Sport or POMS questionnaires (Adam, Brassington et al., 2004; van der Does et al., 2017; Laux et al., 2015; Liederbach & Compagno, 2001a) (Liederbach et al., 1992). RESTQ subscales that correlated to injury, reported by these studies included: fatigue, sleep quality, social recovery, social support, general well-being, personal accomplishment, injury and disturbed breaks.

Four studies reported increased fatigue to be a risk factor for injury. These studies were either related to ballet dancers (using POMS) (Adam et al., 2004; Liederbach & Compagno, 2001) (Liederbach et al., 1992) or sport codes (using RESTQ-52 Sport) (Laux et al., 2015). In the current study, fatigue scores of both gender groups increased significantly from P1 to P2. Low sleep quality (RESTQ subscale) has also been significantly correlated with subsequent injury in professional football players (Laux et al., 2015), while sleep duration has been significantly associated with days off due to injury in professional ballet dancers (Adam et al., 2004).

Both gender groups and the total PGA group levels of performance reported reduced sleep quality in P2. Poor sleep has been associated with daytime sleepiness, substance abuse, reduced concentration, fatigue, and unhealthy eating (Adam et al., 2004), which further increase the risk of injury. The decrease in sleep quality supports previous findings by Fietze et al. (2009), who tested professional ballet dancers during a rehearsal period before a premier. The authors found that dancers' sleep efficiency and duration were already lower than usual for the dancers' age group at the beginning of the study, and that these levels decreased even further over the 67-day testing period.

Social recovery and social support have been reported as important in relation to lowering injury risk and the duration of injury rehabilitation (Adam et al., 2004; Van der Does et al., 2017). Social recovery was lower in P2 for the total group, female dancers and PGA group. Blevins et al. (2019) added that dancers are even more stressed if they do not socialise outside of dance class when they have an injury. Dancers have been reported to be highly motivated and obsessed during vocational dance training. Consequently, they put everything else in life, including socialising, second to dancing, and the imbalance can lead to injury (Blevins et al., 2019). These findings by previous researchers and results from the current study could have implications for ballet dancers. Managing and monitoring the well-being of dancers at the company involved in the current study should include education on the importance of balancing life outside of ballet.

All scales mentioned above that were reported in previous studies showed an increased risk for injury at the end of the year in all or some of the subgroups. It appears that high-stress circumstances during a performance phase cause a decrease in sleep quality, which may increase other stressors and consequently increase dancers' risk for injury. The researcher recommends that sexes and levels be managed individually, according to the scale that correlated significantly with pain for them. Ideally, dancers' recovery-stress states would be monitored and managed individually, as recommended by previous literature (Kellmann, 2010; Kellmann et al., 2001; Kellmann & Kallus, 2001; Moreno et al., 2015).

The researcher recommends that recovery strategies be implemented during extended performance seasons in ballet companies. Cold-water immersion and massage performed directly after sporting events has been shown to improve perceptual measures of recovery and have previously been suggested in literature (Delextrat et al., 2013; Leeder et al., 2012). In addition, cold-water immersion has shown to improve jump performance 24 hours after a match, as opposed to not using any recovery strategy after a match (Delextrat et al., 2013), to decrease inflammation and to reduce the sensation of pain (Leeder et al., 2012). Cold-water immersion is recommended superiorly to massage directly after a performance for female athletes to reduce the perception of general fatigue and leg soreness (Delextrat et al., 2013). Delextrat et al. (2013) suggested cold-water immersion at two-minute intervals for a total of at least 10minutes. Regarding the current study, dancers could be educated on a variety of recovery modalities that could be used. In accordance with the guidelines by Delextrat et al. (2013) cold water immersion could be included as an option.

E. Perceived pain

Pain was measured with an adapted Self-Estimated Functional Inability because of Pain (SEFIP) questionnaire, asking dancers to report a holistic score of how they feel at the end of each day. As previously stated, the specific objectives and hypotheses will be first mentioned. A discussion of the main findings of differences between phases, sexes and levels of performance will follow. RESTQ-76 Sport subscales, injury and physical complaints will also be discussed in this section.

3.1 Pain of dancers during the Rehearsal and Performance Phases

It was hypothesised that perceived pain would be significantly higher during P2 compared to P1. The hypothesis was rejected. There was no significant difference in perceived pain between phases for the total group.

3.2 Pain of male and female dancers

It was hypothesised that there would be no significant difference in perceived pain between male and female dancers. The hypothesis was accepted. No significant difference occurred between sexes.

3.3 Pain of dancers of different performance levels

It was hypothesised that perceived pain would be significantly more in higher-level dancers compared to lower-level dancers during both phases. The hypothesis was rejected. There was no significant difference between levels of performance regarding pain.

Pain reported with the adapted SEFIP questionnaire showed no difference between the two phases for any of the groups. However, the RESTQ questionnaire indicated significantly increased scores in the physical complaints and injury subscales during P2 compared to P1 for all groups. The difference in P2 results of the two measuring tools might be explained by how often the specific questionnaire was completed, in combination with phase-specific factors. The SEFIP questionnaire was submitted online at the end of each day, while the RESTQ was collected by the researcher herself once per week in the morning. The RESTQ reports administered by the researcher had high participation from the dancers. Due to evening performances in P2, dancers had to submit their pain reports at night after performances. The lack of increased pain scores in P2 could be due to the missing pain reports of dancers who did not complete the questionnaire after a performance, especially if they struggled with injury symptoms. Furthermore, no level four pain scores ("can not work in the production because of pain") were reported during any of the phases. A possible explanation for the lack of level four scores, and possibly for the lower pain scores during

P2, might be due to dancers staying away from the dance studio and not completing the SEFIP questionnaire when they were injured to such an extent.

Pain significantly decreased for all dancers from week 1 to week 8 during P2. The decreasing trend was also reflected in the injury and physical complaints RESTQ scales from week 2 to 8. These results are in contrast to the findings of Liederbach and Compagno (2001) who reported 67% of injuries occurred from middle to end of performance season or semester. However the correlation between high fatigue and injury incidences reported by Liederbach and Compagno (2001), seems to be supported by the current study's results. In the current study fatigue scores (RESTQ), similar to the pain, injury and physical complaints scores, also decreased from start to end of P2. The decreasing scores towards the end of the season might seem positive, however all of these RESTQ scales were at average still higher compared to Rehearsal Phase, which means their recovery-stress states were still less favourable in P2 compared to P1.

The current study's RESTQ scores of injury and physical complaints were compared to that of an elite football team's over a season (Faude et al., 2011). Similar to the current study, football players reported more injury and physical complaints in competition season than preparation season. However, dancers consistently showed higher scores compared to the football players' and the 8-week performance season's average physical complaints scores was as high as the football players' highest scores at the end of their competition season. These results suggest that dancers experienced more physical complaints and injury during the season compared to elite football players.

A clear tendency was seen in SEFIP reports for female dancers to report higher pain scores during P2 compared to male dancers. Sobrino et al., (2015) reported a significant difference in injury rate between male and female professional ballet dancers. The authors also reported that female dancers' injury rate was 75.9% higher than male dancers. Injury reports were collected from specialised medical services and showed that overuse injury dominated in terms of type of injury. Classical ballet dancers had the most injuries compared to other ballet styles (contemporary, neoclassical and Spanish ballet). Blevins et al. (2019) also stated that ballet dancers experience higher physical stress than contemporary dancers. Both studies ascribed this to the specific nature and strict technique in classical ballet compared to other styles, making it more difficult to achieve success.

Despite no differences being found between either pain (SEFIP), injury or physical complaints (RESTQ) for levels of performance in the current study, previous research has shown a positive correlation between performance level of dancers and pain/injury reported (Harrison & Ruddock-Hudson, 2017; Jacobs et al., 2017). More experienced and highly ranked ballet dancers have shown to be more likely to report pain scores ≥ 3 on the SEFIP questionnaire and to report injuries compared to lower ranked professional dancers (Harrison & Ruddock-Hudson, 2017a; Jacobs et al., 2017). Dancers reported to have lower pain tolerance and that their bodies became over-sensitised to pain later in their dancing careers compared to earlier (Harrison & Ruddock-Hudson, 2017). Both studies (Harrison & Ruddock-Hudson, 2017; Jacobs et al., 2017) included ballet and other dance styles. The difference between the current study and the previously mentioned two studies' results could be due to the difference in methodology and population. The current study used an adapted SEFIP questionnaire over 16 weeks of the season and included only ballet dancers and not dancers from other dance styles.

A difference in injury rate according to level of performance has been reported also in sport codes. Gatterer et al. (2012) reported that technique level is associated to injury rate in intermediate level soccer teams. Östenberg & Roos (2000) also reported higher injury rates in male and female elite compared to non-elite soccer players over a season.

It is evident in the pain reports of the current study that most dancers consistently have some level of pain. This supports previous literature who reported pain is an integral part of being a ballet dancers and that pain needs to be managed instead of avoided daily (Anderson & Hanrahan, 2008; Harrison & Ruddock-Hudson, 2017b; Jacobs et al., 2017).

The SEFIP pain results remained similar during both phases, contrary to what was expected. The changes in RESTQ subscales seemed more sensitive to injury symptoms than the SEFIP questionnaire used in the current study. Due to the involvement of the researcher during the data collection period, individual dancers would often confide in the researcher regarding high levels of pain. The high pain levels did not always reflect in their daily completed pain reports at the end of the day. It must, however, be emphasised that an adapted version of the SEFIP questionnaire was used, excluding all the different body regions and instead reporting a single holistic pain score. Nevertheless, the RESTQ might be better to use than the SEFIP questionnaire if the RESTQ is collected once every second or third week. This, in addition to injury symptom information, would also give a holistic recovery-stress profile of a dancer while not being time intensive or a high athletic burden.

F. Correlation between pain and internal training load

It was hypothesised that pain would positively correlate with internal training load for all groups. The hypothesis was accepted. Internal TL of all groups showed a significant positive correlation with perceived pain.

The daily internal training load had a weak positive correlation with the pain reported at the end of the day by use of the modified SEFIP questionnaire for all dancers. The change in correlation between pain scores (0–2) and training load from positive to negative as pain increases to level three seems to support the notion that dancers dance through pain to a certain point. Level three pain is described as “much pain, must avoid some movements”, at which point it seems that dancers lower their involvement in training. In practice, it might be valuable to use this information for injury management when a score of three is reported. Restriction of company training should be implemented in order to prevent serious injury. The previously reported culture of ballet dancers dancing through pain should be taken into account with this population during monitoring for injury prevention and management.

In contrast to the current study’s findings, Boeding et al. (2019) reported no statistical correlation between SEFIP scores and training load in dance. The same measuring scales were used (SEFIP, sRPE) and training load was reported at the end of the day including all activities (dance and additional exercise) in both studies. However, pain was only reported once per week (for seven weeks) in Boeding et al. (2019) as opposed to daily, as in the case of the current study. Secondly, an adapted version of the SEFIP questionnaire was used in the current study, reporting a holistic score instead of individual scores for each anatomical region. Thirdly, contemporary dancers made up the population in the Boeding et al. (2019) study, not classical ballet dancers. The population and methodology could explain the contrasting correlation findings.

G. Internal and external training load

Internal training was determined by means of the sRPE method proposed by Foster et al. (2001). The external training load was determined with the use of GPS units, measuring impacts via foot contacts. As previously stated, the specific objectives and hypotheses will be mentioned first. A discussion of the main findings will follow, leading with internal training load, followed by external training load.

2.1 Training load of dancers during the Rehearsal and Performance Phases

a) It was hypothesised that the internal training load would be significantly higher during P2 compared to P1. The hypothesis was accepted. Internal training load of the total group increased significantly from P1 to P2.

b) It was hypothesised that there will be no significant inter-week differences in external training load. The hypothesis was accepted. Weekly impacts did not differ significantly over the eight-week period of P1 for the total group.

2.2 Training load of male and female dancers

It was hypothesised that there will be no significant difference in internal and external training load between male and female dancers throughout the year. The hypothesis was accepted for P1 and rejected for P2. Both internal and external training load showed no difference between sexes in P1, and internal training load was significantly higher for male compared to female dancers in P2.

2.3 Training load of dancers of different performance levels

It was hypothesised that higher-level dancers would have significantly higher internal and external training loads compared to lower-level dancers. The hypothesis was rejected. There was no significant difference in internal or external training load between the levels of performance for either phase.

The only dance studies found, reported sRPE training load for a single session or as a total for the whole week. Due to irregular reporting, the daily sRPE training load was calculated and averaged over one week period instead of adding every day's training load together for each week. Standard deviations were very large for each activity type (total ballet, performance, team practice), but were exceptionally large during performance activity for the female dancers, SP group and PGA group. Even though the team practice and performance did not increase significantly, the total ballet training load did increase significantly in male dancers. Team practice and total ballet decreased significantly for female dancers from P1 to P2.

For the total group, training load increased from P1 to P2. Taking the daily internal training load of the current study to calculate the weekly training load (P1: 4040 ± 2 515AU), the researcher found that the training load was comparable to previous studies that reported on elite amateur ballet and contemporary dancers (4283 ± 2442AU) (Jeffries et al., 2017), and professional contemporary dancers (2500–4750AU) (Boeding et al., 2019).

The intra-sex levels were most evident of the difference in training load between the two seasons. Male-PGA dancers reported significantly higher total ballet training load in P2 compared to P1 and compared to female-PGA dancers. Female-PGA dancers' total ballet training load was significantly lower than the male-PGA sub-group.

When comparing the current study's (van Wyk, 2019) and other professional ballet companies' training hours per week to that of national and international level football players, it is evident that ballet dancers' training volume is much higher. Faude et al. (2011) reported that elite football players are exposed to approximately 1–1.5 match hours and six training hours per week, or 41 match hours and 213 training hours during a 44-week season.

Professional ballet dancers train six to eight hours a day (Costa et al., 2016; Fietze et al., 2009) and rehearse 27.5 hours per week (Ramkumar et al., 2016) in comparison with six hours a week. Dancers perform between 7–10 stage performances per week during non-consecutive performance weeks and one main performance season, or 110 performances per year (Fietze, et al. 2009), compared to 1–1.5 match hours per week. A dance season is 32–47 weeks in duration (Bronner et al., 2014), which is comparable to the football season. According to Cross et al. (2016) professional rugby players had an increased risk for injury if they had an increased accumulative training load that added up to 1 245AU in a week. Some of the company dancers reported higher internal training load than that in a single day, suggesting that they are always at an increased risk for injury.

Liederbach et al. (2006) reported professional ballet dancers jump approximately 230 times in a 1.5-hour technique class. To the researcher's knowledge, this is the only study that has quantified the number of jumps during a ballet class. The current study, however, reports on the total number of vertical impacts of professional ballet dancers during an entire day of company training. According to the manufacturer's guidelines, any impact above 2G are regarded as a 'step'. The average number of impacts of each dancer per day was approximately 640. Most impacts were at a low G-force (3–4.99G), with almost no impacts above 7G. Impacts recorded in the current study for all ranks are high in frequency and low in vector magnitude. The high number of impacts is supportive of the literature stating that most injuries in ballet dancers are overuse injury caused by high repetition (Allen et al., 2012; Nilsson et al., 2001; Ramkumar et al., 2016; Siev-Ner, 2000; Sobrino & Guillén, 2017a; Twitchett et al., 2010).

The number of impacts at a minimum G-force of 3G and 5G respectively would give a dancer an estimated accumulative lateral vector magnitude of 2 080G AU per day. The high repetition impacts put ballet dancers at an increased risk for lower extremity stress fractures. Stress fractures are caused by repetitive loading (Brockwell et al., 2009) and have been shown to be a common injury type in ballet dancers, especially located in the foot and in younger dancers (Kadel et al., 1992; Nilsson et al., 2001; Shah et al., 2005; Sobrino & Guillén, 2017).

Ballet dancers' specific landing biomechanics acquired from jump training for ballet technique serve to protect them to an extent from certain overuse injuries to the lower extremities compared to non-dancer landing techniques (Azevedo et al., 2019; Liederbach et al., 2008) . Nevertheless, it has been suggested that ballet dancers do exercises to improve ankle stability to lower the risk of stress fractures (Ekstrand & Torstveit, 2012; Prochazkova et al., 2014). Other factors applicable to ballet dancers that have been reported to be associated with stress fractures are low body fat percentage, negative catabolism due to dieting (Sundgot-Borgen & Torstveit, 2007), changes of surface (Warden et al., 2007), longer duration of amenorrhea and dancing more than five hours a day (Kadel et al., 1992).

Independent of whether training load was increased for a specific group or not during the Performance Phase, all dancers reported high internal and external daily training loads. The results show that dancers experience high impact load and in general ballet population traits put them at high risk for lower extremity overuse injuries.

H. Correlation between internal and external training load

It was hypothesised that internal training load would significant positively correlate with external training load in dancers. The hypothesis was accepted. The sRPE training load had a significant, but weak, positive correlation with vertical impact load in professional ballet dancers.

Multiple studies across different sport codes have previously reported a significant positive correlation between internal (both objective and subjective) and external training load measuring methods. A few sport codes, which will be discussed below, include: contemporary and ballet (Jeffries et al., 2017; Surgenor & Wyon, 2019), teamgym (Minganti et al., 2010), cricket (Vickery et al., 2017), Australian football (Bartlett et al., 2016), team sports (McLaren et al., 2018). Objective variables used in the mentioned studies include various accelerometer, GPS and heart rate variables. Subjective methods include sRPE training load, RPE and a psychometric questionnaire.

Jeffries et al. (2017) stated that ballet and contemporary dancers showed significant within-individual correlations between sRPE training load and various internal and external training load and intensity measures, as recorded by a questionnaire, accelerometer and HR monitor. It should be highlighted, since it is the most applicable study regarding sport codes, that the correlation of internal training load was not correlated with impact (vector magnitude) during this particular study.

Minganti et al. (2010) monitored female teamgym athletes during tumbling, trampette and floor programmes, and reported a significant correlation between sRPE methods and the Edwards heart rate method. Minganti et al. (2010) also stated that sRPE methods are sensitive to technical skill activities. Vickery et al. (2017) reported significant correlations between sRPE TL and GPS-derived variables in cricket batsmen and medium-fast bowlers. However, the authors emphasised the influence player position has on a player’s response to training load. This could be important to take into consideration when working with ballet dancers since many dance steps are sex-specific (Wyon et al., 2011) and could therefore act as different player positions affecting the demands placed on male versus female dancers. Bartlett et al. (2016) reported moderate to strong correlation between various GPS running variables and intensity measure with the use of post-training RPE scores (collected 10–30 minutes after each session) in professional Australian football players monitored over a period of 27 weeks. Lastly, in a meta-analysis, McLaren et al. (2018) reported a large correlation between sRPE training load and both accelerometer load and number of impacts (>2–5g) for various team sport athletes in training and competition conditions.

Due to the positive correlation between internal and external training load, it can be stated that vertical impact load was higher for male dancers and lower for female dancers during an eight-week performance period compared to an eight-week rehearsal period. The significant difference in impact load between male and female dancers specifically during a performance period should be further investigated in other ballet companies to declare if it is something to which attention should be given during sex-specific injury prevention strategies.

The positive correlation between the two measuring methods support previous literature and also the validity of using the sRPE method (Foster et al., 2001) to monitor training load in professional ballet dancers.

I. Correlation between recovery-stress scales and internal training load

It was hypothesised that internal training load would significant positively correlate with stress scores and have a significant negative correlation with recovery scores of the following week for all groups during both phases. The hypothesis was rejected. Only certain scales correlated with training load in the different groups.

Sport-specific recovery was the scale that significantly correlated with the most sex and level of performance groups over the two phases. Since there is a negative correlation for training load with sport-specific recovery in most cases but not with sport specific stress, it might be suggested that dancers have good stress coping strategies to manage training-specific stress but poor recovery abilities. Alternatively, it might suggest that the increased stress in P2 is caused by aspects other than training load and therefore does not correlate with sport-specific stress scores.

Fixed calendar weeks were used to compare training load with RESTQ scores. However, as mentioned previously, the RESTQ scores were not always taken on the same day due to the dance schedule. While the researcher aimed to let the three days prior to RESTQ completion be one rest day followed by two days of training, this was not always possible; especially during P2. The few significant correlations could also possibly be explained by the difference in monitoring design and time frame compared to other studies that collected RESTQ less frequent than once per week.

Various studies have reported on the significant effect training load has on recovery-stress states during different training phases of a season. A majority of these studies showed that high training loads are associated with unfavourable recovery-stress states and reported that this occurs either in competition seasons or in an overload phase. Different sport codes included in these studies are: rowing (Kellmann et al., 2001), swimming (Nagle et al., 2015; Nicolas et al., 2019; Nunes et al., 2014), soccer (Thorpe et al. 2011), dance (Jeffries et al., 2017), Australian football (Faude et al., 2011) and rugby. In some instances, a single total recovery-stress score was reported. This was indicative of high stress and low recovery (Nagle et al., 2015; Nunes et al., 2014). Other studies reported on all or some of the four main RESTQ-Sport scales (Faude et al., 2011; Nicolas et al., 2019). Lastly, monitoring tools other than the RESTQ-Sport have also been used (Thorpe et al., 2011).

In literature mentioned, not all scales correlated with training load in all phases and studies. Nicolas et al. (2019) reported a positive correlation between subjective training load (sRPE method) and all stress scales, but a negative correlation with only certain recovery scales during different training phases of a swimming season. Only during the tapering phase did all main stress scales positively (total stress, sport-specific stress, general stress) and all main recovery scales negatively (total recovery, sport-specific recovery, general recovery) correlate with training load. Faude et al. (2011) also reported a moderate correlation of the total stress score with cumulated total Australian football exposure hours. Contrastingly, Hartwig et al. (2009) reported inverted correlations, stating that high training load correlated with low stress and high recovery scores in elite adolescent rugby playing males. The authors ascribed their findings to the specific population maturity level (adolescent), stating that the players were busy with preparation for a prestige game and that they were likely well-conditioned, motivated and talented players.

Despite literature supporting the sensitivity of total stress and total recovery scores to acute and chronic training load, Saw et al. (2016) suggested that it is important to investigate the responsiveness of subscales during monitoring. The authors concluded that the following subscales are sensitive to both training conditions: fatigue, physical recovery, general well-being and being in shape. In other studies, using different measuring tools, training load also correlated to fatigue, sleep quality, soreness and motivation in elite soccer players (Thorpe et al., 2011), and/or contemporary dance and ballet (Jeffries et al. 2017). The relative similarity in the mentioned aspects between the studies supports the importance of these aspects in the monitoring and management of recovery-stress balances in athletes with high training load demands. These factors should be further investigated to determine the significance thereof in professional ballet dancers, as well as how the monitoring of these subscales in the RESTQ can be used to identify high-risk dancers during prolonged performance seasons.

In the current study, female dancers reported higher stress scores and lower recovery scores in P2 despite a decrease in internal training load. This could be an indication of the significant effect that non-training related stressors have on dancers' recovery-stress states, especially during a prolonged performance season. Although athletes can endure high stress demands for short periods of time (e.g. three weeks) (Faude et al., 2011), Faude et al. (2011) stated that accumulated fatigue over a prolonged period could affect performance and injury risk.

Ballet companies' main performance seasons can continue for approximately two months. It is therefore important to manage recovery-stress states of dancers during this time, but also prior this period to ensure that dancers are optimally recovered to start a long and demanding performance season. Nunes et al. (2014) reported a two-week tapering period with significantly lower internal training load restored balances of female elite athletes' recovery-stress states after an overload phase. Although only low sport-specific recovery scales correlated significantly with training load in the current study's total group during P2, a two-week tapering period could be incorporated into the schedule a professional ballet company prior to the start of performance season. This could potentially restore recovery-stress states and optimally prepare dancers for the start of the performance season.

J. Summary of main findings

From the findings in this study, ballet dancers of the involved company are at a high risk for overuse injuries and developing overtraining syndrome towards the end of the ballet season. It is clear that the dancers had disturbed recovery-stress states during their main performance season (towards the end of the ballet season). Training phase and sex were the main determinants for recovery-stress states, with all groups showing more stress in P2. Female dancers showed lower recovery scores in P2 than P1. Female dancers' recovery scores were also lower than male dancers', therefore increasing their risk of overtraining and injury.

Internal and external training load correlated significantly with the lower recovery-stress state scores. Dancers are exposed to very high impact load and internal training load daily, and training load was higher for the total group during P2 than P1. Intra-sex levels of performance were most evident of the changes in training load across the two phases. Injury, physical complaints and fatigue were increased for all groups during P2, and sleep quality was lower for all groups.

A summary of the aims, objectives hypothesis and outcomes of significant differences found between two phases of a professional dance season, between male and female dancers, as well as dancers of different levels of performance, are provided in.

Table 5.1 **Summary of the aims, objectives, hypothesis and main findings of significant differences and correlations among dancers and between phases.**

Aim	Objective	Accept/reject hypothesis	Outcome
1. Recovery-stress state	1.1 Phases	A	1.1 Stress P1<P2 Recovery P1>P2 1.2 Stress M=F Recovery M>F (P2) 1.3 Stress and recovery SP=PGA
	1.2 Sexes	R	
	1.4 Levels	R	
2. Internal training load (sRPE)	2.1 Phases	A	2.1 P1<P2
	2.2 Sexes	R	2.2 P1 M=F, P2 M>F
	2.4 Levels	R	2.3 SP=PGA
3. External training load (Impacts) (P1)	3.1 Inter-week	A	3.1 No difference in impact load 3.2 M=F 3.3 SP=PGA
	3.2 Sexes	A	
	3.3 Levels	R	
4.Perceived pain	4.1 Phases	R	4.1 P1=P2
	4.2 Sexes	A	4.2 M=F
	4.3 Levels	R	4.3 SP=PGA
5.Correlations	5.1 RESTQ: SEFIP 5.1.1 Total group	A	5.1.1 Correlated with selected scales in P1 and P2

	5.1.2 Sexes 5.1.3 Levels		5.1.2 M and F correlated with selected with scales 5.1.3 SP and PGA correlated with selected scales
	5.2 RESTQ: sRPE 5.2.1 Total group 5.2.2 Sexes 5.2.3 Levels	R	5.2.1 Pain positively correlated with recovery (P2) 5.2.2 M and F correlated with unique scales 5.2.3 SP and PGA correlated with unique scales (P2)
	5.3 sRPE: SEFIP 5.3.1 Total group 5.3.2 Sexes 5.3.3 Levels	A	5.3 All groups positively correlated
	5.4 sRPE: Impacts	A	5.4 Positive correlation

Note: RESTQ = Recovery-Stress Questionnaire for Athletes, SEFIP = Self-Estimated Functional Inability because of Pain, P1 = Rehearsal Phase, P2 = Performance Phase, M = Male, F = Female, SP = Lower-level dancers, PGA = Higher-level dancers

STUDY LIMITATIONS AND FUTURE RESEARCH

Limitations

There were a number of limitations in the current study. During the P2, consistency in reporting daily training load and pain at the end of the day was more problematic and the researcher had to regularly remind dancers to submit their online reports. A few data sets were lost due to GPS technical difficulties (battery, recording failure) or dancers who came too late to class to be able to get fitted with a GPS prior start of class. Isolating each dancer's active session for GPS data analysis was challenging when dancers performed different parts in the rehearsal and started late or left rehearsal early. Consequently, the specific data points were not always easy to determine and led to the discarding of some GPS data for correlations. Sometimes sRPE training load could not be reported after each session due to dancers' tight schedules and was often reported at the end of the day from what the dancers remembered about each session. This could have affected accuracy of session duration and sRPE score. Only dancers from one company was included in the study and therefore findings cannot extrapolate to dancers from all other companies, since other companies might be managed differently.

Recommendations for future research

The correlation between pain and RESTQ-Sport sub-scales should be investigated individually to give a more accurate indication of which scales are more sensitive of subsequent pain in dancers. Furthermore, it is recommended that the correlation between internal training load and the RESTQ-Sport subscales injury as well as physical complaints be assessed to determine if those scales show a different correlation than the SEFIP questionnaire. Regarding the education of dancers on recovery, it could be helpful to conduct a survey to determine the dancers' knowledge, perceptions and practices of recovery modalities.

CONCLUSION AND RECOMMENDATIONS

The current study set out to determine the physical, physiological and psychosocial demands of a rehearsal and a performance phase of a professional ballet season. Findings indicated recovery-stress states are sex- and training phase sensitive. The end of a season posed a higher risk for injuries and overtraining in all dancers, but especially in female dancers. Overall, the performance phase at the end of the ballet season was marked with high stress levels, increased internal training and impact load and low recovery levels. The positive correlation between both training load and fatigue with pain, emphasises the importance of recovery during performance seasons, especially at the end of the ballet year.

Looking at the training and performance schedules of the company, it would seem as if a science-based periodised training and recovery plan is not implemented. This is, however, speculation because the researcher did not analyse the company's training programme.

Recommendations

- Dancers should be educated on the different aspects of fatigue, how to monitor it themselves by (e.g. self-awareness) and on different recovery strategies that can be implemented to address different aspects of recovery.
- Companies should monitor recovery-stress states continuously throughout the ballet season. Dancers showing to be at high risk for overtraining should be addressed with the appropriate intervention to rebalance their recovery-stress state.
- Recovery strategies should be implemented to promote recovery during demanding periods, especially during extended performance seasons but also prior the extended performance season in order to assure dancers are optimally recovered before the demanding season starts
- Training periodisation should be implemented in company schedules to ensure optimal performance and lower the risk for injury and overtraining.
- Female dancers recovered less than male dancers during an extended performance season. Special care should be taken to address the low recovery abilities in female dancers during demanding phases.
- To lower stress and anxiety levels during performance seasons, dancers need to feel in control.

REFERENCES

A Brief History of Ballet - Illustrated by Pittsburgh Ballet Theatre. [online]. Available: https://www.pbt.org/learn-and-engage/resources-audience-members/ballet-101/brief-history-ballet/ [2019, 2 Dec.].

Adam, M.U., Brassington, G.S., Steiner, H. & Matheson, G.O. 2004. Psychological factors associated with performance-limiting injuries in professional ballet dancers. Journal of Dance Medicine and Science. 8(2):43–46.

Air, M. & Rietveld, B. 2008. Dance-specific, Graded Rehabilitation: medical problems. 23(3):16.

Alexandre, D., Silva, C.D. Da, Hill-Haas, S., Wong, D.P., Natali, A.J., De Lima, J.R.P., Filho, M.G.B.B., Marins, J.J.C.B., et al. 2012.

Allen, N. & Wyon, M. 2008. Dance Medicine: Athlete or Artist. Sport Ex Medicine. 35(January 2008):6–9. [Online], Available: http://www.researchgate.net/publication/229070486_Dance_Medicine_Athlete_or_Artist.

Allen, N., Nevill, A., Brooks, J., Koutedakis, Y. & Wyon, M. 2012. Ballet Injuries: Injury Incidence and Severity Over 1 Year. Journal of Orthopaedic & Sports Physical Therapy. 42(9):781-A1.

Anderson, R. & Hanrahan, S.J. 2008. Dancing in Pain. Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science. 12(1):9–16. [Online], Available: http://www.ncbi.nlm.nih.gov/pubmed/19618573.

Armstrong, R. 2019. Dance Screening Practices in Dance Companies, dance schools, and university programs. OA Journal of Clinical Case Reports . 1(007):1–14.

Askling, C., Saartok, T. & Thorstensson, A. 2006. Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level. British Journal of Sports Medicine. 40(1):40–44.

Azevedo, A.M., Oliveira, R., Vaz, J.R. & Cortes, N. 2019. Professional Dancers Distinct Biomechanical Pattern during Multidirectional Landings. Medicine and Science in Sports and Exercise. 51(3):539–547.

Bakdash, J.Z. & Marusich, L.R. 2017. Repeated measures correlation. Frontiers in Psychology. 8(MAR):1–13.

Baldari, C. & Guidetti, L. 2001. VO2max, ventilatory and anaerobic thresholds in rhythmic gymnasts and young female dancers. Journal of Sports Medicine and Physical Fitness. 41(2):177–182.

Banks, S. & Dinges, D.F. 2007. Behavioral and physiological consequences of sleep restriction. Journal of Clinical Sleep Medicine. 3(5):519–528.

Bartlett, J.D., O'Connor, F., Pitchford, N., Torres-Ronda, L. & Robertson, S.J. 2016.

Relationships Between Internal and External Training Load in Team-Sport Athletes: Evidence for an Individualized Approach. International Journal of Sports Physiology and Performance. 12(2):230–234.

Beato, M., Devereux, G. & Stiff, A. 2018. Validity and Reliability of Global Positioning System Units (STATSports Viper) for Measuring Distance and Peak Speed in Sports. Journal of strength and conditioning research. 32(10):2831–2837.

Benson, J., Gillien, D.M., Bourdet, K. & Loosli, A.R. 1985. Inadequate Nutrition and Chronic Calorie Restriction in Adolescent Ballerinas. The Physician and Sportsmedicine. 13(10):79–90.

Blevins, P., Hopper, L., Erskine, S., Moyle, G. & Blevins, P. 2013. Overtraining and recovery in dance : A case study approach Correspondence. 30–31.

Boeding, J.R.E., Visser, E., Meuffels, D.E. & de Vos, R.J. 2019. Is Training Load Associated with Symptoms of Overuse Injury in Dancers? A Prospective Observational Study. Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science. 23(1):11–16.

Bosch, C. 2019. Joburg Ballet. Company manager. Email conversation.

Brink, M.S., Visscher, C., Coutts, A.J. & Lemmink, K.A.P.M. 2012a. Changes in perceived stress and recovery in overreached young elite soccer players. Scandinavian Journal of Medicine and Science in Sports. 22(2):285–292.

Brink, M.S., Visscher, C., Coutts, A.J. & Lemmink, K.A.P.M. 2012b. Changes in perceived stress and recovery in overreached young elite soccer players. Scandinavian Journal of Medicine and Science in Sports. 22(2):285–292.

Brockwell, J., Yeung, Y. & Griffith, J.F. 2009. Stress Fractures of the Foot and Ankle. (October).

Bronner, S., Ojofeitimi, S. & Mayers, L. 2006. Comprehensive Surveillance of Dance Injuries A Proposal for Uniform Reporting Guidelines for Professional Companies. Journal of Dance Medicine & Science. 10(3–4):69–80. [Online], Available: http://www.ingentaconnect.com/content/jmrp/jdms/2006/00000010/F0020003/art00001.

Bronner, S., Ojofeitimi, S., Lora, J.B., Southwick, H., Kulak, M.C., Gamboa, J., Rooney, M., Gilman, G., et al. 2014. A Preseason Cardiorespiratory Profile of Dancers in Nine Professional Ballet and Modern Companies. Journal of Dance Medicine & Science. 18(2):74–85.

Burgess, D.J. 2017. The Research Doesn’t Always Apply: Practical Solutions to Evidence-Based Training-Load Monitoring in Elite Team Sports. International Journal of Sports Physiology and Performance. 12(s2):S2-136-S2-141.

Calmeiro, L., Tenenbaum, G. & Eccles, D.W. illia. 2014a. Managing pressure: patterns of appraisals and coping strategies of non-elite and elite athletes during competition. Journal of sports sciences. 32(19):1813–1820.

Calmeiro, L., Tenenbaum, G. & Eccles, D.W. illia. 2014b. Managing pressure: patterns of appraisals and coping strategies of non-elite and elite athletes during competition. Journal of sports sciences. 32(19):1813–1820.

Christen, J., Foster, C., Porcari, J.P. & Mikat, R.P. 2016. Temporal robustness of the session rating of perceived exertion. International Journal of Sports Physiology and Performance. 11(8):1088–1093.

Codonhato, R., Rubio, V., Pereira Oliveira, P.M., Resende, C.F., Martins Rosa, B.A., Pujals, C. & Fiorese, L. 2018. Resilience, stress and injuries in the context of the Brazilian elite rhythmic gymnastics. PLoS ONE. 13(12):1–16.

Cohen, J.L., Segal, K.R., Witrol, I. & McArdle, W.D. 1982. Cardiorespiratory responses to ballet exercise and the VO2 of elite ballet dancers. Medicine and science in sports and exercise. 14(3):212–217.

Cohen, J.L., Segal, K.R. & McArdle, W.D. 1982. Heart Rate Response to Ballet Stage Performance. Physican ans Sports Medicine. 10(11):120–133.

Cormack, S.J., Smith, R.L., Mooney, M.M., Young, W.B. & Brien, B.J.O. 2014. Accelerometer Load as a Measure of Activity Profile in Different Standards of Netball Match Play. 283–291.

Costa, M.S.S., Ferreira, A.S., Orsini, M., Silva, E.B. & Felicio, L.R. 2016. Characteristics and prevalence of musculoskeletal injury in professional and non-professional ballet dancers. Brazilian Journal of Physical Therapy. 20(2):166–175.

Cross, M.J., Williams, S., Trewartha, G., Kemp, S.P.T. & Stokes, K.A. 2016. The Influence of In-Season Training Loads on Injury Risk in Professional Rugby Union. International Journal of Sports Physiology and Performance. 11(3):350–355.

Dahlström, M., Jansson, E., Nordevang, E. & Kaijsery, L. 1990. Discrepancy between estimated energy intake and requirement in female dancers. Clinical Physiology. 10(1):11–25.

Daprati, E., Iosa, M. & Haggard, P. 2009. A dance to the music of time: Aesthetically-relevant changes in body posture in performing art. PLoS ONE. 4(3):e5023.

Delextrat, A., Calleja-González, J., Hippocrate, A. & Clarke, N.D. 2013. Effects of sports massage and intermittent cold-water immersion on recovery from matches by basketball players. Journal of Sports Sciences. 31(1):11–19.

Van der Does, H.T.D., Brink, M.S., Otter, R.T.A., Visscher, C. & Lemmink, K.A.P.M. 2017. Injury Risk Is Increased by Changes in Perceived Recovery of Team Sport Players. Clinical Journal of Sport Medicine. 27(1):46–51.

Edmonds, R., Wood, M., Fehling, P. & DiPasquale, S. 2018. The Impact of a Ballet and Modern Dance Performance on Heart Rate Variability in Collegiate Dancers. Sports. 7(1):3.

Ekstrand, J. & Torstveit, M.K. 2012. Stress fractures in elite male football players.

Scandinavian Journal of Medicine and Science in Sports. 22(3):341–346.

Esposito, F., Impellizzeri, F.M., Margonato, V., Vanni, R., Pizzini, G. & Veicsteinas, A. 2004. Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur soccer players. European Journal of Applied Physiology. 93(1–2):167–172.

Etikan, I., Musa, S.A. & Alkassim, R.S. 2016. Comparison of Convenience Sampling and Purposive Sampling Comparison of Convenience Sampling and Purposive Sampling. American Journal of Theoretical and Applied Statistics. 5(January 2016):1–5.

Faude, O., Kellmann, M., Ammann, T., Schnittker, R. & Meyer, T. 2011. Seasonal changes in stress indicators in high level football. International Journal of Sports Medicine. 32(4):259–265.

Fietze, I., Strauch, J., Holzhausen, M., Glos, M., Theobald, C., Lehnkering, H. & Penzel, T. 2009. Sleep quality in professional ballet dancers. Chronobiology International. 26(6):1249–1262.

Filho, E., di Fronso, S., Forzini, F., Murgia, M., Agostini, T., Bortoli, L., Robazza, C. & Bertollo, M. 2015. Athletic performance and recovery–stress factors in cycling: An ever changing balance. European Journal of Sport Science. 15(8):671–680.

Fiolkowski, P. and Bauer, J., 1997. The effects of different dance surfaces on plantar pressures. Journal of Dance Medicine & Science, 1(2), pp.62-66.

Foster, C., Daines, E., Hector, L.L., Snyder, A.C. & Welsh, R. 1996. Athletic performance in relation to training load. Wisconsin medical journal. 95(6):370–374.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P. & Dodge, C. 2001. A new approach to monitoring exercise training. Journal of strength and conditioning research. 15(1):109–115.

Di Fronso, S., Nakamura, F.Y., Bortoli, L., Robazza, C. & Bertollo, M. 2013. Stress and recovery balance in amateur basketball players: Differences by gender and preparation phase. International Journal of Sports Physiology and Performance. 8(6):618–622.

Gatterer, H., Ruedl, G., Faulhaber, M., Regele, M. & Burtscher, M. 2012. Effects of the performance level and the FIFA "11" injury prevention program on the injury rate in Italian male amateur soccer players. Journal of Sports Medicine and Physical Fitness. 52:80–4.

Grove, J.R., Main, L.C. & Sharp, L. 2013. Stressors, Recovery Processes, and Manifestations of Training Distress in Dance. Journal of Dance Medicine & Science. 17(2):70–78.

Guidetti, L., Gallotta, M., Emerenziani, G. & Baldari, C. 2007. Exercise Intensities during a Ballet Lesson in Female Adolescents with Different Technical Ability. International Journal of Sports Medicine. 28(9):736–742.

Guidetti, L., Emerenziani, G. Pietro, Gallotta, M.C. & Baldari, C. 2007. Effect of warm up on energy cost and energy sources of a ballet dance exercise. European Journal of

Applied Physiology. 99(3):275–281.

Haddad, M., Stylianides, G., Djaoui, L., Dellal, A. & Chamari, K. 2017.

Halson, S.L. 2013. Recovery techniques for athletes. Sports Science Exchange. 26(120):1–6. [Online], Available: http://jmg.bmj.com/cgi/doi/10.1136/jmg.2003.014902.

Halson, S.L. 2014a. Monitoring Training Load to Understand Fatigue in Athletes. Sports Medicine. 44(S2):139–147.

Halson, S.L. 2014b. Monitoring Fatigue and Recovery. Sports Science Exchange. 27(135):1–6. [Online], Available: https://secure.footprint.net/gatorade/stg/gssiweb/pdf/SSE_135_Halson.pdf.

Harrison, C. & Ruddock-Hudson, M. 2017a. Pushing the pain barriers because the show must go on. Journal of Science and Medicine in Sport. 20:e21.

Harrison, C. & Ruddock-Hudson, M. 2017b. Perceptions of Pain, Injury, and Transition-Retirement. Journal of dance medicine & science. 21(2):43–52.

Hartwig, T.B., Naughton, G. & Searl, J. 2009. Load, stress, and recovery in adolescent rugby union players during a competitive season. Journal of Sports Sciences. 27(10):1087–1094.

Hattie, J., Marsh, H.W., Neill, J.T. & Richards, G.E. 1997. Adventure Education and Outward Bound: Out-of-Class Experiences That Make a Lasting Difference. Review of Educational Research. 67(1):43–87.

Heidari, J., Beckmann, J., Bertollo, M., Brink, M., Kallus, K.W., Robazza, C. & Kellmann, M. 2019. Multidimensional monitoring of recovery status and implications for performance. International Journal of Sports Physiology and Performance. 14(1):2–8.

Herbrich, L., Pfeiffer, E., Lehmkuhl, U. & Schneider, N. 2011. Anorexia athletica in pre-professional ballet dancers. Journal of Sports Sciences. 29(11):1115–1123.

Herman, L., Foster, C., Maher, M., Mikat, R. & Porcari, J. 2006. Validity and reliability of the session RPE method for monitoring exercise training intensity. South African Journal of Sports Medicine. 18(1):14–17.

Impellizzeri, F.M., Rampinini, E., Coutts, A.J., Sassi, A. & Marcora, S.M. 2004. Use of RPE-based training load in soccer. Medicine and Science in Sports and Exercise. 36(6):1042–1047.

Jacobs, C.L., Cassidy, J.D., Côté, P., Boyle, E., Ramel, E., Ammendolia, C., Hartvigsen, J. & Schwartz, I. 2017. Musculoskeletal injury in professional dancers: Prevalence and associated factors: An international cross-sectional study. Clinical Journal of Sport Medicine. 27(2):153–160.

Jeffries, A.C., Wallace, L. & Coutts, A.J. 2017. Quantifying training loads in contemporary dance. International Journal of Sports Physiology and Performance. 12(6):796–802.

Jeukendrup, A. & Gleeson, M. 2004. Sport Nutrition: An Introduction to Energy Production and Performance. 1st Editio ed. Human Kinetics.

Kadel, N.J., Teitz, C.C. & Kronmal, R.A. 1992. Stress fractures in ballet dancers. The American Journal of Sports Medicine. 20(4):445–449.

Kallus, K.W. & Gaisbachgrabner, K. 2017. Stress and recovery in applied settings: Long working hours, recovery, and breaks. In 1st ed. M. Kellmann & J. Beckmann (eds.). aBINGDON, uk: Routledge Sport, Recovery, and Performance: Interdisciplinary Insights. 233–246.

Kellmann, M. 2010. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. Scandinavian Journal of Medicine & Science in Sports. 20(SUPPL. 3):95–102.

Kellmann, M. & Kallus, W.K. 2001. The Recovery-Stress Questionnaires : User Manual.

Kellmann, M., Alternburg, D., Lormes, W. & Steinacker, J.M. 2001. Assessing Stress and Recovery During Preparation for the World Championships in Rowing. The Sport Psychologist. 15:151–167.

Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A.J., Duffield, R., Erlacher, D., Halson, S.L., et al. 2018. Recovery and Performance in Sport: Consensus Statement. International Journal of Sports Physiology and Performance. 13(2):240–245.

Kelly, S.J., Murphy, A.J., Watsford, M.L., Austin, D. & Rennie, M. 2015. Reliability and Validity of Sports Accelerometers During Static and Dynamic Testing. International Journal of Sports Physiology and Performance. 10(1):106–111.

Koutedakis, Y. & Jamurtas, A. 2004. The dancer as a performing athlete: Physiological considerations. Sports Medicine. 34(10):651–661.

Koutedakis, Y., Myszkewycz, L., Soulas, D., Papapostolou, V., Sullivan, I. & Sharp, N.C.C. 1999.

Kreher, J.B. & Schwartz, J.B. 2012. Overtraining Syndrome: A Practical Guide. Sports Health. 4(2):128–138.

Kulig, K., Fietzer, A.L. & Popovich, J.M. 2011. Ground reaction forces and knee mechanics in the weight acceptance phase of a dance leap take-off and landing. Journal of Sports Sciences. 29(2):125–131.

Laux, P., Krumm, B., Diers, M. & Flor, H. 2015. Recovery–stress balance and injury risk in professional football players: a prospective study. Journal of Sports Sciences. 33(20):2140–2148.

Laws, H., Apps, J., Bramley, I. & Parker, D. 2005. Fit to dance 2. London: Dance UK.

Lee, C. 2002. Ballet in western culture: a history of its origins and evolution. New York: Routledge.

Leeder, J., Gissane, C., van Someren, K., Gregson, W. & Howatson, G. 2012. Cold water immersion and recovery from strenuous exercise: a meta-analysis. British Journal of

Sports Medicine. 46(4):233–240.

Lewis, E.J., Howard, T. & O'Connor, F.G. 2009. Overtraining. In Elsevier Netter's Sport Edition 1. 800.

Liederbach, M. & Compagno, J. 2001. Psychological aspects of fatigue-related injury in dance. Journal of Dance Medicine & Science. 5(4):116–120.

Liederbach, M., Richardson, M., Rodriguez, M., Compagno, J., Dilgen, F. & Rose, D. 2006. Jump exposures in the dance training environment: a measure of ergonomic demand. J Athl Train. 41(2):S85.

Liederbach, M., Dilgen, F.E. & Rose, D.J. 2008. Incidence of anterior cruciate ligament injuries among elite ballet and modern dancers: A 5-year prospective study. American Journal of Sports Medicine. 36(9):1779–1788.

Liederbach, M., Hagins, M., Gamboa, J.M. & Welsh, T.M. 2012. Assessing and Reporting Dancer Capacities, Risk Factors, and Injuries. Journal of Dance Medicine & Science. 16(4):139–153.

Lorenz, D.S., Reiman, M.P. & Walker, J.C. 2010. Periodization: Current review and suggested implementation for athletic rehabilitation. Sports Health. 2(6):509–518.

McLain, D. 1983. Artistic development in the dancer. Clinics in sports medicine. 2(3):563–570.

McLaren, S.J., Macpherson, T.W., Coutts, A.J., Hurst, C., Spears, I.R. & Weston, M. 2018. The Relationships Between Internal and External Measures of Training Load and Intensity in Team Sports: A Meta-Analysis. Sports Medicine. 48(3):641–658.

McNair, D.M., Lorr, M. & Droppleman, L.F. 1992. Manual for the profile of mood states (POMS). San Diego: Educational and Industrial Testing Service.

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., Raglin, J., Rietjens, G., et al. 2013. Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the european college of sport science and the American College of Sports Medicine. Medicine and Science in Sports and Exercise. 45(1):186–205.

Micheli, L.J., Casella, M., Faigenbaum, A.D., Southwick, H. & Ho, V. 2005. Preseason to Postseason Changes in Body Composition of Professional Ballet Dancers. Journal of Dance Medicine & Science. 9(2):56–59. [Online], Available: http://ezproxy.library.yorku.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=sph&AN=18715686&site=ehost-live.

Minganti, C., Capranica, L., Meeusen, R., Amici, S. & Piacentini, M.F. 2010. The validity of session-rating of perceived exertion method for quantifying training load in teamgym. Journal of Strength and Conditioning Research. 24(11):3063–3068.

Moreno, J., Ramos-Castro, J., Rodas, G., Tarragó, J.R. & Capdevila, L. 2015. Individual recovery profiles in basketball players. Spanish Journal of Psychology. 18(2015):1–10.

Murgia, C. 2013. Overuse, Tissue Fatigue, and Injuries. Journal of Dance Medicine &

Science. 17(3):92–100.

Nagle, J., McMillan, J., Munkasy, B., Joyner, A., Roorda, A., Scott, M. & Rossi, S. 2015. Changes in Swim Performance and Perceived Stress and Recovery in Female Collegiate Swimmers Across a Competitive Season. Journal of Swimming Research. 23:44–53.

Nicolas, M., Vacher, P., Martinent, G. & Mourot, L. 2019. Monitoring stress and recovery states: Structural and external stages of the short version of the RESTQ sport in elite swimmers before championships. Journal of Sport and Health Science. 8(1):77–88.

Nilsson, C., Leanderson, J., Wykman, A. & Strender, L.E. 2001. The injury panorama in a Swedish professional ballet company. Knee Surgery, Sports Traumatology, Arthroscopy. 9(4):242–246.

Nunes, J.A., Moreira, A., Crewther, B.T., Nosaka, K., Viveiros, L. & Aoki, M.S. 2014. Monitoring training load, recovery-stress state, immune-endocrine responses, and physical performance in elite female basketball players during a periodized training program. Journal of Strength and Conditioning Research. 28(10):2973–2980.

O'Neal, E.K., McIntosh, J.R., Coates, T.E., Hornsby, J.H., Green, J.M. & Killen, L.L. 2013. Influence of Terminal RPE on Session RPE. Journal of Strength and Conditioning Research. 27(10):2800–2805.

Orishimo, K.F., Kremenic, I.J., Pappas, E., Hagins, M. & Liederbach, M. 2009. Comparison of landing biomechanics between male and female professional dancers. American Journal of Sports Medicine. 37(11):2187–2193.

Östenberg, A. & Roos, H. 2000. Injury risk factors in female European football. A prospective study of 123 players during one season. Scandinavian Journal of Medicine and Science in Sports. 10(5):279–285.

Otter, R.T.A., Brink, M.S., Van Der Does, H.T.D. & Lemmink, K.A.P.M. 2015. Monitoring Perceived Stress and Recovery in Relation to Cycling Performance in Female Athletes. International Journal of Sports Medicine. 37(1):12–18.

Pouliot-Laforte, A., Veilleux, L.-N., Rauch, F. & Lemay, M. 2014. Validity of an accelerometer as a vertical ground reaction force measuring device in healthy children and adolescents and in children and adolescents with osteogenesis imperfecta type I. Journal of musculoskeletal & neuronal interactions neuronal interactions. 14(2):155–161.

Prochazkova, M., Tepla, L., Svoboda, Z., Janura, M. & Cieslarová, M. 2014. Analysis of foot load during ballet dancers' gait. Acta of Bioengineering and Biomechanics. 16(2):41–45.

Ramel, E.M., Moritz, U. & Jarnlo, G.-B. 1999. Validation of a pain questionnaire (SEFIP) for dancers with a specially created test battery. Medical Problems of Performing Artists. 14(December 1999):196–203. [Online], Available: http://www.prevent.se/Documents/prevent.se/arbetsmiljoarbete/systematiskt arbetmiljoarbete/hjalpdokument/hjalpdokument_scen_eng_dancers_self-estimated.pdf.

Ramkumar, P.N., Farber, J., Arnouk, J., Varner, K.E. & Mcculloch, P.C. 2016. Injuries in a Professional Ballet Dance Company: A 10-year Retrospective Study. Journal of Dance Medicine & Science. 20(1):30–37.

Redding, E. & Wyon, M. 2003. Strengths and weaknesses of current methods for evaluating the aerobic power of dancers. Journal of Dance Medicine & Science. 7(1):10–16. [Online], Available: http://articles.sirc.ca/search.cfm?id=S-881786%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&db=sph&AN=SPHS-881786&site=ehost-live.

Redding, E., Wyon, M., Shearman, J. & Doggart, L. 2004. Validity of Using Heart Rate as a Predictor of Oxygen Consumption in Dance. Journa of Dance Medicine and Science. 8(3):69–73.

Rodrigues-Krause, J., Krause, M., Cunha, G. dos S., Perin, D., Martins, J.B., Alberton, C.L., Schaun, M.I., De Bittencourt, P.I.H., et al. 2014. Ballet dancers cardiorespiratory, oxidative and muscle damage responses to classes and rehearsals. European Journal of Sport Science. 14(3):199–208.

Rodrigues-Krause, J., dos Santos Cunha, G., Alberton, C.L., Follmer, B., Krause, M. & Reischak-Oliveira, A. 2014. Oxygen Consumption and Heart Rate Responses to Isolated Ballet Exercise Sets. Journal of Dance Medicine & Science. 18(3):99–105.

Rodrigues-Krause, J., Krause, M. & Reischak-Oliveira, A. 2015. Cardiorespiratory Considerations in Dance. Journal of Dance Medicine and Science. 19(3):91–102.

Roe, G., Darrall-jones, J., Black, C., Shaw, W., Till, K. & Jones, B. 2017. Validity of 10-HZ GPS and Timing Gates for Assessing Maximum Velocity in Professional Rugby Union Players. International Journal of Sports Physiology and Performance. 12(6):836–839.

Rush, E.C., Goedecke, J.H., Jennings, C., Micklesfield, L., Dugas, L., Lambert, E. V. & Plank, L.D. 2007. BMI, fat and muscle differences in urban women of five ethnicities from two countries. International Journal of Obesity. 31(8):1232–1239.

Sachs, S. 1937. World history of the dance. Newyork W.W. Norton & company, 1937.

Sanders, D.J., Walker, A.J., Prior, K.E., Poyssick, A.N. & Arent, S.M. 2019. Training Demands and Physiological Profile of Cross-Disciplined Collegiate Female Dancers. Journal of Strength and Conditioning Research. (2):1–5.

Saw, A.E., Main, L.C. & Gastin, P.B. 2016. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. British Journal of Sports Medicine. 50(5):281–291.

Schantz, P.G. & Strand, P.-O. 1984. Physiological characteristics of classical ballet. Medicine & Science in Sports & Exercise. 16(5):472–476.

Scott, M.T.U., Scott, T.J. & Kelly, V.G. 2016. The Validity and Reliability of Global Positioning Systems in Team Sport: A Brief Review. Journal of Strength and

Conditioning Research. 30(5):1470–1490.

Shah, S., Luftman, J. & Vigil, D. V. 2005. Stress injury of the talar dome and body in a ballerina. Journal of Dance Medicine & Science. 9(3–4):91–95. [Online], Available: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=2009114175&site=ehost-live.

Siev-Ner, I. 2000. Common overuse injuries of the foot and ankle in dancers. Journal of Dance Medicine & Science. 4(2):49–53.

da Silva, A.M.B., Enumo, S.R.F., de Araújo, M.F., Carvalho, L. de F., Bittencourt, I.G., Afonso, R. de M. & Luz, T.S.R. 2016. Adaptação e evidências de validade do Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) para dançarinos adolescentes (RESTQ-Dance). Estudos de Psicologia. 21(3):249–260.

Da Silva, C.C., Goldberg, T.B.L., Soares-Caldeira, L.F., Oliveira, R. dos S., de Paula Ramos, S. & Nakamura, F.Y. 2015. The Effects of 17 Weeks of Ballet Training on the Autonomic Modulation, Hormonal and General Biochemical Profile of Female Adolescents. Journal of Human Kinetics. 47(1):61–71.

Smith, D. & Norris, S. 2002. Training load and monitoring an athlete's tolerance for endurance training. In M. Kellmann (ed.). Champaign, IL: Human Kinetics Enhancing recovery: preventing underperformance in athletes. 81–101.

Smith, P.J., Gerrie, B.J., Varner, K.E., Mcculloch, P.C., Lintner, D.M. & Harris, J.D. 2015. Incidence and Prevalence of Musculoskeletal Injury in Ballet: A Systematic Review. Orthopaedic Journal of Sports Medicine. 3(7):31–34.

Sobrino, F.J. & Guillén, P. 2017a. Overuse Injuries in Professional Ballet: Influence of Age and Years of Professional Practice. Orthopaedic Journal of Sports Medicine. 5(6):6–11.

Sobrino, F.J. & Guillén, P. 2017b. Overuse Injuries in Professional Ballet: Influence of Age and Years of Professional Practice. Orthopaedic Journal of Sports Medicine. 5(6):6–11.

Sobrino, F.J., de la Cuadra, C. & Guillén, P. 2015. Overuse Injuries in Professional Ballet: Injury-Based Differences Among Ballet Disciplines. Orthopaedic Journal of Sports Medicine. 3(6):1–7.

Surgenor, B. & Wyon, M. 2019. Measuring Training Load in Dance: The Construct Validity of Session-RPE. Medical Problems of Performing Artists. 34(1):1–5.

Thorpe, R., Strudwick, A., Buchheit, M., Atkinson, G., Drust, B. & Gregson, W. n.d. The tracking of morning fatigue status across in-season training weeks in elite soccer players.

Thorpe, R.T., Sturdwich, A.J., Buchheit, M., Atkinson, G., Drust, B. & Gregson, W. 2011. The Tracking of Morning Fatigue Status Across In-Season Training Weeks in Elite Soccer Players. Int. J. Sport Nutr. Exerc. Metab. (January):1–13.

Tibana, R., de Sousa, N., Voltarelli, F., Prestes, J., Fett, C., Cunha, G. & Gabbett, T. 2018. Validity of Session Rating Perceived Exertion Method for Quantifying Internal

Training Load during High-Intensity Functional Training. Sports. 6(3):68.

Tudor, O.B. 1999. Periodization: theory and methodology of training. 4th ed. ed. United States of America: Human Kinetics.

Twitchett, E., Angioi, M., Metsios, G.S., Koutedakis, Y. & Wyon, M. 2008. Body composition and ballet injuries: A preliminary study. Medical Problems of Performing Artists. 23(3):93–98.

Twitchett, E., Angioi, M., Koutedakis, Y. & Wyon, M. 2009. Video Analysis of Classical Ballet Performance. Journal of Dance Medicine & Science. 13(4):124–128.

Twitchett, E., Angioi, M., Koutedakis, Y. & Wyon, M. 2010. The demands of a working day among female professional ballet dancers. Journal of Dance Medicine & Science. 14(4):127–32. [Online], Available: http://www.ncbi.nlm.nih.gov/pubmed/21703083.

Twitchett, E., Brodrick, A., Nevill, A.M., Koutedakis, Y., Angioi, M. & Wyon, M. 2010. Does Physical Fitness Affect Injury Occurrence and Time Loss Due to Injury in Elite Vocational Ballet. Journal of Dance Medicine & Science. 14(1):26–31.

Twitchett, E.A., Koutedakis, Y. & Wyon, M.A. 2009. Physiological fitness and professional classical ballet performance: a brief review. Journal of strength and conditioning research / National Strength & Conditioning Association. 23(9):2732–2740.

Van Wyk, R. 2019. Cape Town City Ballet. Artistic director. Email conversation.

Venter, R., Potgieter, J. & Barnard, J. 2010. The use of recovery modalities by elite South African team athletes. South African Journal for Research in Sport, Physical Education and Recreation. 32(1):133–145.

Vickery, W., Dascombe, B. & Duffield, R. 2017. The Association Between Internal and External Measures of Training Load in Batsmen and Medium-Fast Bowlers During Net-Based Cricket Training. International Journal of Sports Physiology and Performance. 12(2):247–253.

Walker, I.J. & Nordin-Bates, S.M. 2010. Performance anxiety experiences of professional ballet dancers: the importance of control. Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science. 14(4):133–145.

Walter, H.L., Docherty, C.L. & Schrader, J. 2011. Ground reaction forces in ballet dancers landing in flat shoes versus pointe shoes. Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science. 15(2):61–4. [Online], Available: http://www.ncbi.nlm.nih.gov/pubmed/21703094.

Warden, S.J., Creaby, M.W., Bryant, A.L. and Crossley, K.M., 2007. Stress fracture risk factors in female football players and their clinical implications. British journal of sports medicine, 41(1):i38-i43.

Wilmerding, M.V., McKinnon, M.M. & Mermier, C. 2005. Body Composition in Dancers. Journal of Dance Medicine & Science. 9(1):18–23.

Wundersitz, D.W.T., Gastin, P., Robertson, S.J. & Davey, P.C. 2015. Validation of a Trunk-mounted Accelerometer to Measure Peak Impacts Validation of a Trunk-mounted Accelerometer to Measure Peak Impacts during Team Sport Movements. (March).

Wyon, M. 2010. Preparing to perform. Journal of Dance Medicine & Science. 14(2):67–72. [Online], Available: http://cep.lse.ac.uk/centrepiece.

Wyon, M. 2012. Supplemental Physical Fitness Training Can Improve the Artistic Elements of Dance Performance. International Association for Dance Medecine and Science. 4(1):7–9. [Online], Available: http://c.ymcdn.com/sites/www.iadms.org/resource/resmgr/imported/info/Bulletin_for_Teachers_4-1_pp7-9_Wyon.pdf.

Wyon, M. 2014. Towards a new training methodology. In Vol. 01 ArtEZ Press. 111–118.

Wyon, M.A., Abt, G., Redding, E., Head, A. and Sharp, C.N., 2004. Oxygen uptake during modern dance class, rehearsal, and performance. The Journal of Strength & Conditioning Research, 18(3), pp.646-649.

Wyon, M.A. & Redding, E. 2005. Physiological monitoring of cardiorespiratory adaptations during rehearsal and performance of contemporary dance. Journal of Strength and Conditioning Research. 19(3):611–614.

Wyon, M., Allen, N., Cloak, R., Beck, S., Davies, P., Clarke, F. (2016) Assessment of maximum aerobic capacity and anaerobic threshold of elite ballet dancers. Medical Problems in Performing Artists 31 (3):145-149

Wyon, M., Redding, E., Abt, G., Head, A. & Sharp, N.C.C. 2003. Development, Reliability, and Validity of a Multistage Dance Specific Aerobic Fitness Test (DAFT). Journal of Dance Medicine & Science. 7(3):80–84.

Wyon, M.A., Abt, G., Redding, E., Head, A. & Sharp, N.C.C. 2004. Oxygen uptake during modern dance class, rehearsal and performance. Journal of Strength and Conditioning Research. 18(3):646–649.

Wyon, M.A., Twitchett, E., Angioi, M., Clarke, F., Metsios, G. & Koutedakis, Y. 2011. Time Motion and Video Analysis of Classical Ballet and Contemporary Dance Performance. International Journal of Sports Medicine. 32(11):851–855.

Zanini, G. de S., Filho, D.M.P., Neiva, C.M., Da Silva, D.P., Ciolac, E.G. & Verardi, C.E.L. 2018. Stress and mood states monitoring in a swimming team during a competitive period. Journal of Physical Education and Sport. 18(4):2466–2471.

APPENDIX A

Definitions of the RESTQ-76 Sport scales adapted from (Kellmann & Kallus, 2001).

		SCALE	SUMMARY
General	Stress	**General Stress**	Subjects with high scores describe themselves as being frequently mentally stressed, depressed, unbalanced, and listless.
		Emotional Stress	Subjects with high scores experience frequent irritation, aggression, anxiety, and inhibition.
		Social Stress	Subjects who experience frequent arguments, fights, irritation concerning others, general upset, and lack of humour will have score high on this level.
		Conflicts/Pressure	High scores on this level of the scale are preceded by unsettled conflicts, unpleasant things that needed to be done, goals that could not be reached, and thoughts that could not be dismissed.
		Fatigue	Time pressure in job, training, school and life, being constantly disturbed during important work, over fatigue, and lack of sleep characterize this area of stress.
		Lack of Energy	This scale manifests in ineffective work behaviour, like the inability to concentrate, lack of energy and compromised decision-making ability.
		Physical Complaints	Characteristics of this scale are physical indisposition and complaints that relate to the whole body.
	Recovery	**Success**	Success, pleasure at work, and creativity during the previous few days are assessed on this scale.
		Social Recovery	Dancers who have frequent pleasurable social contact and change combined with relaxation and

			amusement have high scores on this scale.
		Physical Recovery	Physical recovery, physical well-being and fitness are assessed on this scale.
		General Well-Being	Frequent good moods and feeling of well-being, general relaxation and contentment display in high scores on this scale.
		Sleep Quality	Sufficient recovering sleep, an absence of sleeping disorders while falling asleep, and sleeping through the night, characterize quality sleep.
Sport-Specific	**Stress**	**Disturbed Breaks**	This scale deals with recovery deficits, interrupted recovery, and situations that disturb periods of rest (e.g. teammates, coaches).
		Emotional Exhaustion	Dancers who feel burned out and want to quit their sport will score high on this level.
		Injury	High scores signal an acute injury or vulnerability to injury.
	Recovery	**Being in Shape**	Dancers with high scores describe themselves as fit, physically efficient and full of vitality.
		Personal Accomplishment	High scores are reached by dancers who feel integrated in their team, communicate well with their teammates and enjoy their sport.
		Self-Efficacy	This scale is characterized by how convinced the dancer is that he/she has trained well and is optimally prepared.
		Self-Regulation	Dancers' mental skills to prepare, push, motivate and set goals for themselves are assessed by this scale.

APPENDIX B

PRE-PARTICIPATION QUESTIONNAIRE

Name			
Surname			
Date of birth			
Cellphone number			
Email address			
Additional training participation	What:	How long:	How often:
Smoking habits (if YES, how much)	YES	NO	
	Cigarettes per day:		

Ballet career	
Age when started doing ballet	
Current position in company	
Amount of years dancing professionally	

Injuries	
Current physical problems (past two weeks)	

APPENDIX C

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

Recovery-Stress States and Training Load of Professional Ballet Dancers during a Rehearsal and Performance Phase of a Ballet Year

You are asked to participate in a research study conducted by Prof R.E. Venter (PhD), Dr E.K. Africa (PhD) and Jana de Wet (BScHons Biokinetics) from the Department of Sport Science at Stellenbosch University. The results will be used as part of a master's thesis study. You were selected as a possible participant in this study because you are a full time contracted professional ballet dancer in the Western Cape above 18 years of age and injury free.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine a relationship between workload and selected psychophysical variables in professional male and female ballet dancers during rehearsal and performance phases.

2. PROCEDURES

If you volunteer to participate in this study, you will be asked to do the following things:

Daily document your ballet training hours, rate the day's training intensity on a scale, report any additional training done or recovery modalities implemented and report your musculoskeletal pain on a scale. Once per week, for the duration of the day's ballet training, selective participants will be required to dance with a Global positioning system (GPS) and in the morning of the same day fill in a stress-recovery questionnaire.

Your height will be measured in the first week of the study and your weight every four weeks during testing periods (two phases of eight weeks each).

3. POTENTIAL RISKS AND DISCOMFORTS

The researcher will be on-site and she is a registered biokineticist with a First aid level 1 qualification. In an event of a medical emergency the closest emergency unit be contacted (tel: 021 404 9111) and participant will be transported there. The procedures and activities used in this research project involve no serious risks to the participants. No harm will be done to the well-being of the participants and no invasive procedures are included in the study. GPS-vest has the possibility to be slightly uncomfortable, but various sizes will be available for best fit.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

At the end of the research study, participants and members of Cape Town City Ballet (CTCB) company will be invited to attend a presentation where all data will be shared with them. Participants will receive their own results of the study and have access to the master's thesis. The ballet company should benefit from the research by receiving a summary of the results obtained from the participants.

5. PAYMENT FOR PARTICIPATION

Participants will not receive payment for participation. Each participant will however receive a summary report of their results and have access to the completed master's study.

6. CONFIDENTIALITY

All information obtained throughout this study will be handled with confidentiality and any information that can be identified with you, will be kept confidential. Any personal information will only be disclosed with your permission or as may be required by law. Any forms that have been completed by you and all data collection forms will be kept in a locked room at the Department Sport Science, Stellenbosch University. Electronic data will be kept on a password protected external hard drive or computer, and access will be limited to the researcher and the study supervisors. None of this information will be communicated to your company's staff. Results of the study will be published in a reputable journal with no personal information being published. Any data published will be general and individuals will not be named.

7. PARTICIPATION AND WITHDRAWAL

Participation in this study is completely voluntary and you may withdraw from the study at any time, without any consequences. Should there be any questions that you do not want to answer, you may refuse to answer the questions and still remain in the study. Should specific circumstances arise, the researcher may withdraw you from the study.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Jana de Wet (Cell: +27 82 546 4349, E-mail: janasdewet@gmail.com), Prof R.E. Venter (Tel: +27 21 808 4721, rev@sun.ac.za; Sport Science Department, US), Dr E.K. Africa (Tel: +27 (0)21 808 4591, africa@sun.ac.za, Sport Science Department, US).

9. RIGHTS OF RESEARCH SUBJECTS

Participation discontinuation or withdrawal of your consent may be done at any time. No penalty will be involved, should any of the mentioned occur. No legal claims, rights or remedies are being waved because of your participation in the study. Any questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT

The information above was described to me, ____________________________________ in Afrikaans or English by Jana de Wet. I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

____

Name of Participant

____ ______________

Signature of Participant Date

SIGNATURE OF INVESTIGATOR

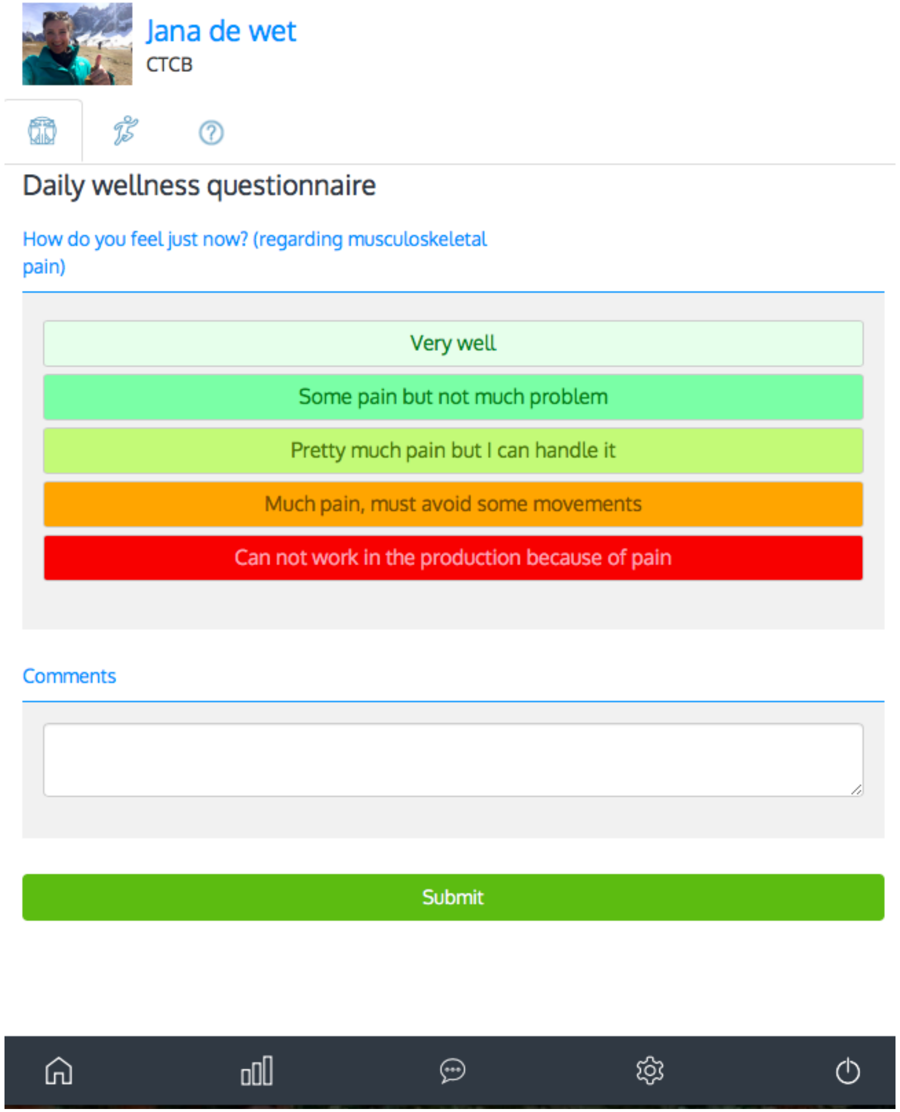
I declare that I explained the information given in this document to __________________________.

She/He was encouraged and given ample time to ask me any questions. This conversation was conducted in Afrikaans or English and no translator was used.

____ ______________

Signature of Investigator Date

APPENDIX D

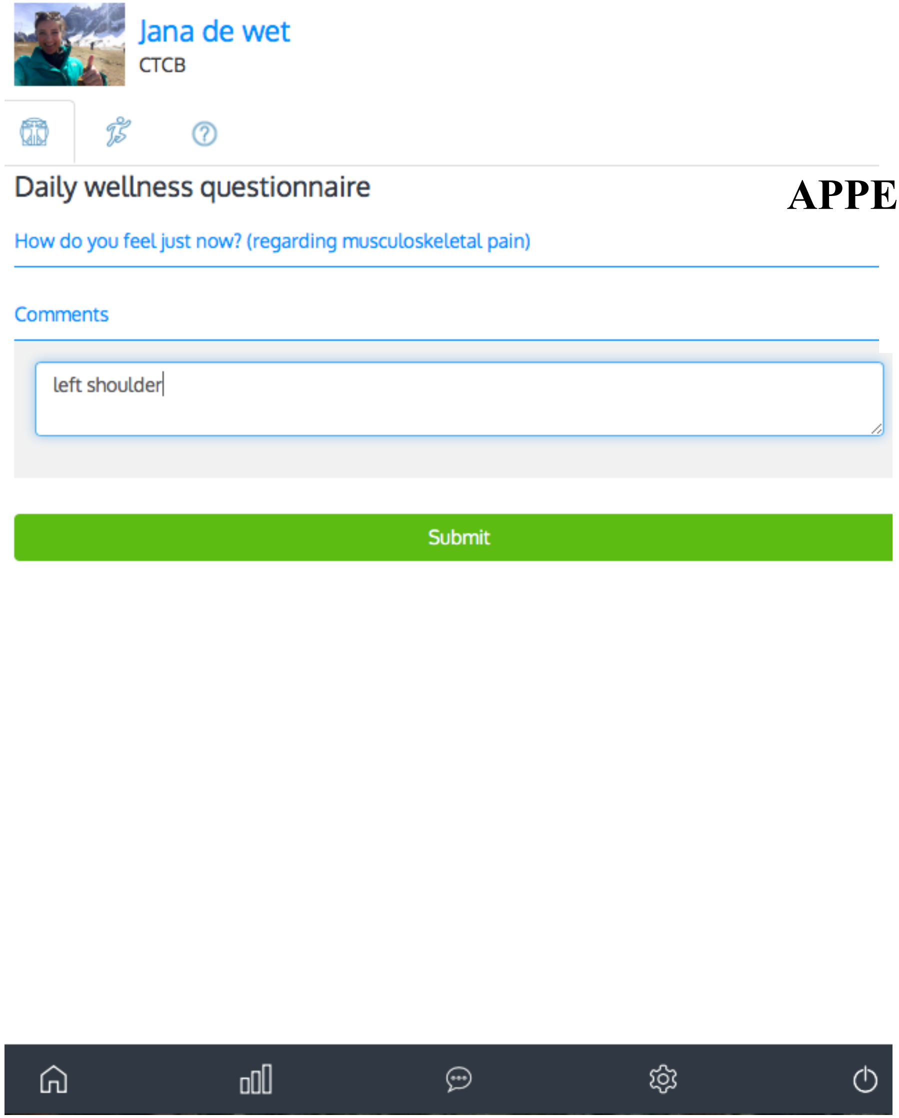


Jana de wet
CTCB

Daily wellness questionnaire

How do you feel just now? (regarding musculoskeletal pain)

Comments



Jana de wet
CTCB

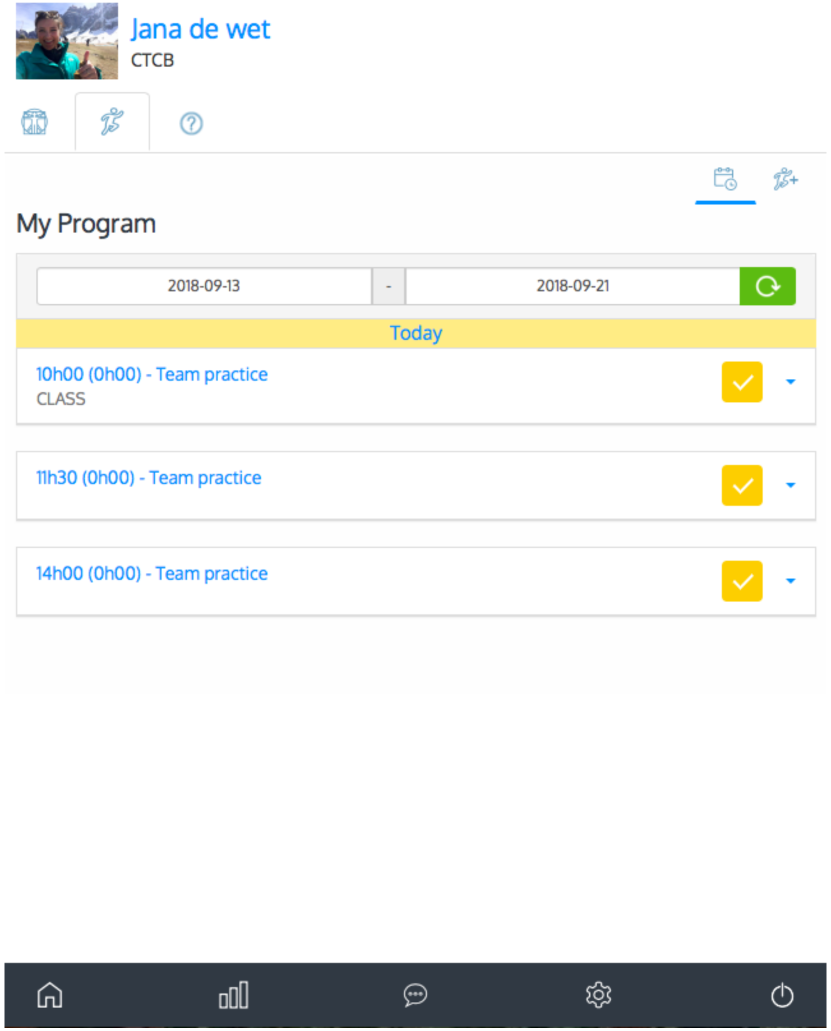
Daily wellness questionnaire

How do you feel just now? (regarding musculoskeletal pain)

Comments

left shoulder

APPENDIX D



Jana de wet
CTCB

My Program

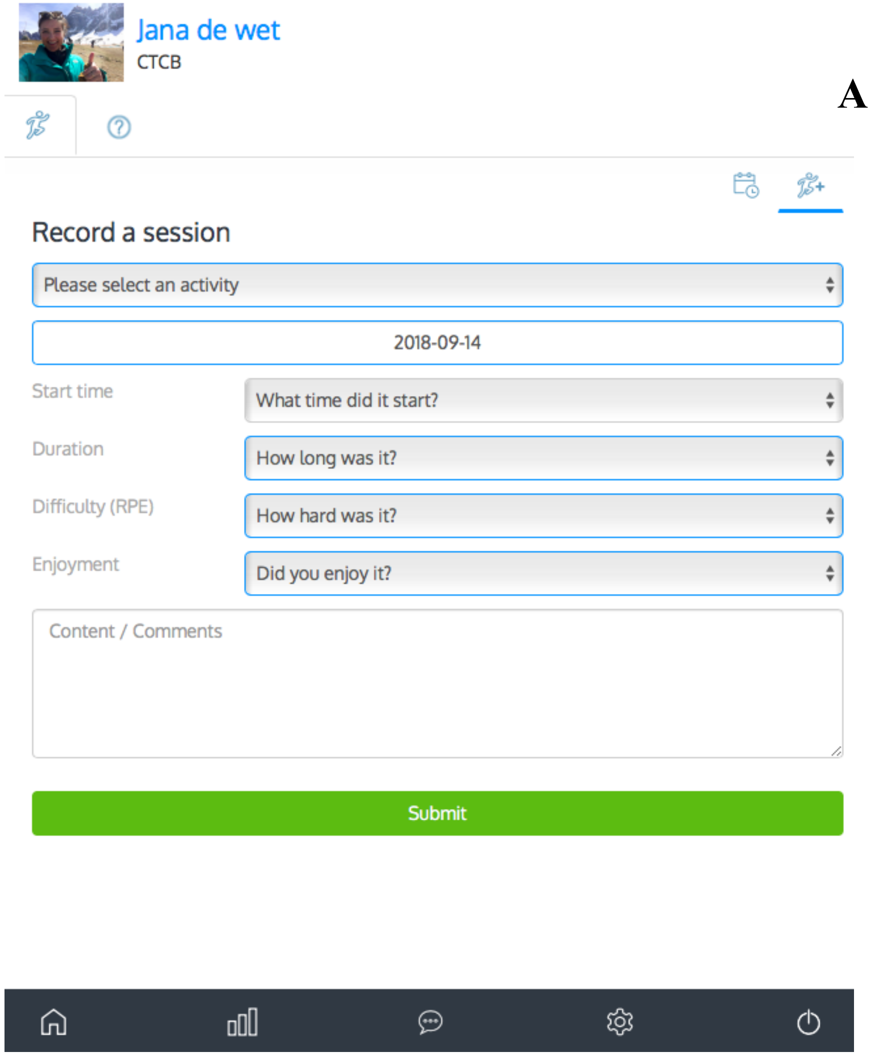
2018-09-13 - 2018-09-21

Today

10h00 (0h00) - Team practice
CLASS

11h30 (0h00) - Team practice

14h00 (0h00) - Team practice



Jana de wet
CTCB

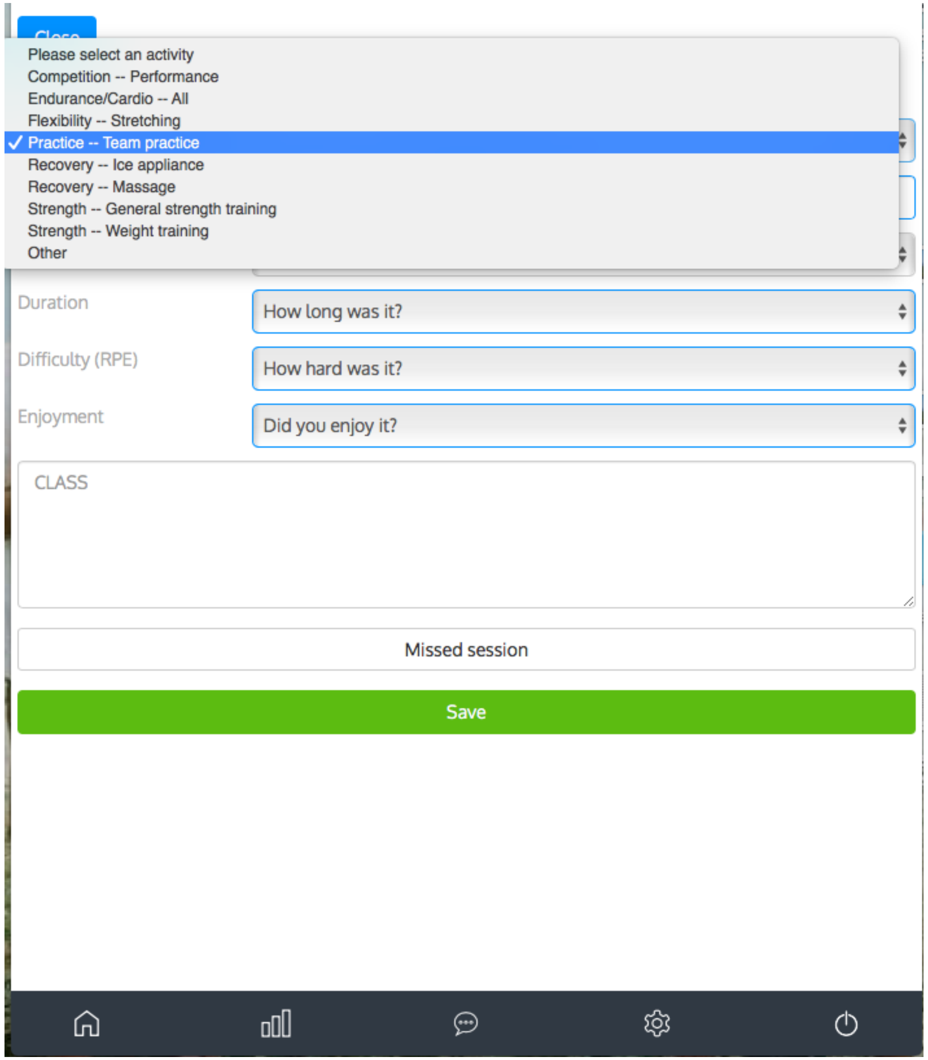
Record a session

Please select an activity

2018-09-14

Start time: What time did it start?
Duration: How long was it?
Difficulty (RPE): How hard was it?
Enjoyment: Did you enjoy it?

Content / Comments


Close
Please select an activity
Competition -- Performance
Endurance/Cardio -- All
Flexibility -- Stretching
✓ Practice -- Team practice
Recovery -- Ice appliance
Recovery -- Massage
Strength -- General strength training
Strength -- Weight training
Other
Duration
How long was it?
Difficulty (RPE)
How hard was it?
Enjoyment
Did you enjoy it?
CLASS
Missed session
Save