Longitudinal Assessment of Physical, Physiological and Psychological Characteristics of Elite Circus Student-Artists

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ABSTRACT

Introduction: Circus arts has seen rapid growth over the past thirty years, and artists require a unique combination of technical, physical, and artistic abilities with a performance schedule and culture that is distinct from sport. Yet, the development of elite circus artists continues to rely on sport-based and traditional circus training methods. Research into critical performance and health factors in a circus student-artist context would provide valuable insight for the development of modern circus training and injury prevention strategies. The aim of this manuscript-style dissertation is to characterize physical, physiological, and psychological factors in a high-performance circus training environment.

Manuscript 1: Sleep and Fatigue of Elite Circus Student-Artists During One Year of Training

- **Authors**: Decker, A., Aubertin, P., & Kriellaars, D.
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Manuscript 2: Body composition adaptations throughout an elite circus student-artist training season

- **Authors:** Decker, A., Aubertin, P., & Kriellaars, D.
- **Status:** Accepted for publication in Journal of Dance Medicine and Science (2020)

Manuscript 3: Year-long variation of psychological characteristics of student-artists in an elite circus arts training program

- **Authors:** Decker, A., Cairney, J., Jefferies, P., Aubertin, P., & Kriellaars, D.
- **Status:** In preparation for submission to Work and Stress

Manuscript 4: Putative mechanisms of elevated injury rates after vacation break in elite circus artist students

- **Authors:** Decker, A., Stuckey, M., Fleet, R., Aubertin, P., & Kriellaars, D.
- **Status:** Accepted book chapter in Circus Medicine (publication in 2020)

Information from this thesis can be used by circus coaches, artists, and performance science and medicine personnel to guide future research and influence the training methods of circus artists, globally.

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And most of all, a very special thank you to my advisor, Dr. Dean Kriellaars. Your mentorship, guidance, and friendship has changed my life. Words cannot express my gratitude for all that you have done for me.

Dedication

I dedicate this work to my incredible wife, Leigh Anne. My doctoral studies required substantial financial, time, and social sacrifices, which, admittedly, were not always easy. Through it all, your love and support never wavered. Thank you and I love you!

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Background

The creation of Cirque du Soleil in 1984 brought mainstream attention to a shift from traditional circuses like Ringling Bros. and Barnum & Bailey to a new age of circus arts. While tents, clowns, and jugglers remain fixtures in contemporary circus, the addition of high-end sound and light systems, story-telling, large-capacity venues, elaborate costumes and make-up, and new disciplines, such as extreme skating, motocross, and break-dancing, helped reshape the circus industry to a focus on spectacular movement, artistry, and innovation[1,2].

The transition from traditional to modern circus has led to unprecedented interest and growth in circus arts. At the professional level, Cirque du Soleil, the world's best-known professional circus company, now employs over 5000 employees worldwide, has performed shows in over 250 cities, and brings in annual revenues nearing $1 billion[3]. The creation and growth of additional professional companies, such as Cirque Eloize (Canada), NoFit State Circus (Wales), and Circa Contemporary Circus (Australia), to name only a few, has emphasized the need to develop elite-level circus artists who are ready to perform on the global stage.

To meet this need, over 650 circus arts training centres in more than fifty countries around the world are now operational[4]. Professional circus schools, like Montreal's renowned Ecole nationale de cirque (ENC), created in 1981, offer college degree programs, blending

academics with technical and artistic development, to develop circus artists for the professional ranks. A more detailed description of ENC is provided in the overview of methodology and in manuscript 1.

Circus arts has also found its way into social programs and its use in the education system is increasing, too. Social circus programs, such as those offered through Cirque du Soleil's Cirque du Monde division, aim to combine the positive social aspects and fun of circus and integrate them into community-level social programs to enhance engagement[5]. Physical education programs also utilize circus arts instruction to develop creativity, physical literacy and resiliency in children[6].

While the reach of circus arts and opportunities for artist development have certainly expanded and evolved, the development methodologies used to develop up-and-coming circus artists continues to largely rely on traditional circus practices[1], with some application of sport training approaches. The circus industry's reliance on sport training approaches and traditional circus methodologies has led to substantial gaps in knowledge regarding performance optimization in contemporary circus arts training. While, at face value, circus arts shares a natural affiliation with sports like gymnastics through their shared acrobatic elements, sport training approaches may not be suitable for developing circus student-artists[7,8]. At ENC, several distinctions from collegiate sport programs are evident, including: the lack of a defined competitive "in-season" and travel requirements; unique training apparatuses[3]; a strong emphasis on esthetics (body composition, make-up, costumes)[9]; the self-identification of students as artists rather than as athletes[2]; that

student-artists are immersed within a student body that is entirely composed of other student-artists; an emphasis on emotional connection with the audience[2]; the requirement of student-artists to train in all disciplines (diversity in movement repertoire) rather than exclusive development (physical proficiency) in one "position"; and high staff to student ratios. The distinctions between collegiate athletes and developing circus artists makes the direct extrapolation of sport research to circus application a questionable practice.

Given the dearth of circus-specific research, it is essential that we begin to develop a circus-specific body of knowledge. To begin to fill these knowledge gaps, a Performance Optimization Framework, informed by the knowledge translation framework of the Canadian Institute of Health Research, based on the work of Straus et al.[10], was contextualized in conjunction with the National Research Chair for Circus Arts, Patrice Aubertin, and the Scientific Director at the Centre de recherche, d'innovation et de transfert en arts du cirque (Center for Circus Arts Research, Innovation and Knowledge Transfer; CRITAC), Dr. Dean Kriellaars. The framework places an emphasis on the importance of characterizing critical performance factors in a circus-specific context to afford circus coaches, performance science and medicine personnel, and artists the ability to use research-driven best practice to guide performance monitoring and intervention strategies specific to the needs of circus student-artists.

Within the Performance Optimization Framework (Figure 1), an "actionable dashboard" was developed. The dashboard was designed with knowledge translation[11] at its foundation to facilitate the generation of new knowledge and its practical implementation

in the fledgling circus research enterprise. The dashboard was unique in that it mandated that any new scientific investigation at ENC would be designed with an immediate knowledge articulation strategy for practitioners simultaneously with scientific publication.

At the measurement level of the dashboard, key physical, physiological and psychological factors which could be important to optimal performance of circus student-artists were identified.

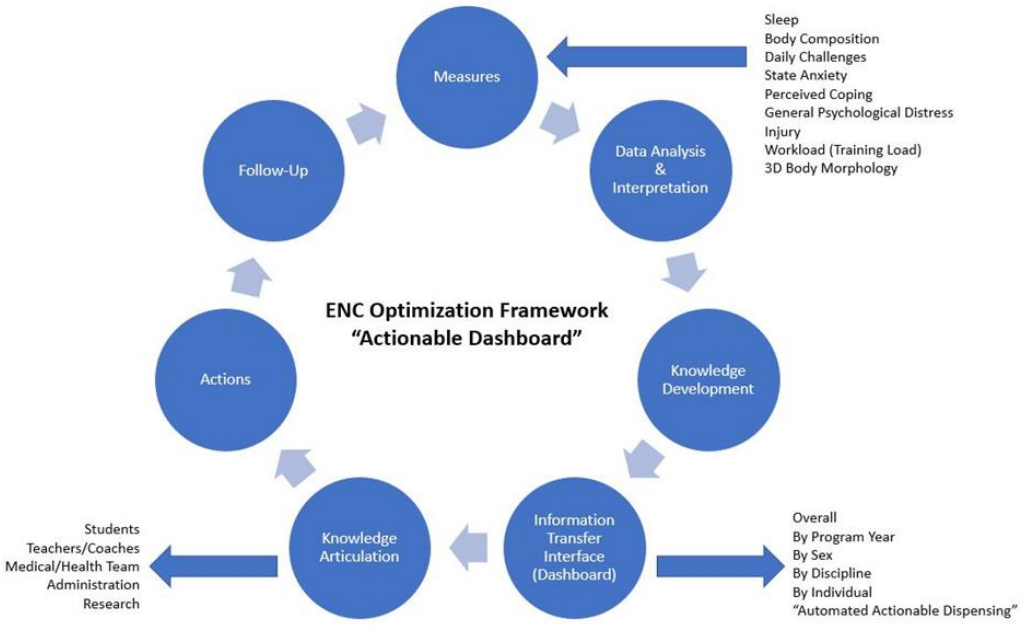

Figure 1. Actionable Dashboard of Performance Optimization Framework

This thesis was developed within the context of the Performance Optimization Framework and focused on a select list of factors that were deemed important and practically capable of investigation within the demanding context of ENC. The primary items identified for the

knowledge translation enterprise were sleep[12,13], body composition[14,15], daily hassles (challenges)[16,17], and injury[18].

A brief overview of each topic is provided below as background to the methodological overview and the four individual manuscripts which make up the results section of this thesis.

Sleep

In high-performance environments outside of circus arts (e.g., sport, military), sleep has been identified as a critical factor for health and performance[19,20]. Within these environments, inadequate sleep has been shown to negatively affect immune function[19], metabolism[21], emotional state[22], and decision-making and information processing[23]. Sleep has also been shown to influence physical and psychomotor performance across a variety of domains, including accuracy[24], power[25], isokinetic strength[26], endurance[27], and reaction time[28]. Despite a body of literature demonstrating the importance of sleep to health and performance, athletes in the sport context often fail to attain adequate sleep[13,29].

The sleep hygiene of elite circus student-artists and professional artists has yet to be explored. A characterization of circus student-artists' sleep practices would provide valuable information to coaches, science and medicine staff, and artists to optimize performance and health. In a circus student-artist training context (like at ENC), there are environmental differences distinct from sport that could influence the sleep hygiene practices of student-artists; student-artists do not require travel associated with

competition, their training year spans the entire scholastic year, and they endure a very diverse schedule (see Appendix 1) that conceptually varies in demands (physical, technical and artistic) through the training year. These contextual differences from sport emphasize the importance of an exploration of sleep hygiene in a circus context.

Body Composition

In sport, body composition assessment has proven useful to predict and assess fitness and performance[30], benchmark development and return-to-play timelines[31], make tactical decisions[32], identify talent[33], and monitor symptoms of overtraining[34]. Due to the fact that changes in training load[35], diet[36], training mode[37], and injury status[38] have been shown to influence variations in body composition over competitive sport seasons, cross-sectional measurements of body composition fail to capture its dynamic nature[39].

To date, there is an absence of literature regarding the body composition of elite circus student-artists. Longitudinal tracking of body composition would provide valuable insight into adaptations that occur within a demanding circus training environment and confirmation that the bodies of the student-artists are adequately prepared for performance in the professional circus ranks. Further, it would allow for documentation of sex- and discipline-specific differences in body composition. Finally, the impact of extended time-off on body composition could also be assessed, which is important to understand in training optimization and injury prevention programming, particularly in an

environment in which student-artists are given two periods of extended vacation; summer and winter break.

In the circus context, a wide variety of body morphologies are sought, making circus an inclusive setting through its diversity. However, despite the inclusive aspects of circus, within many disciplines the esthetic of the performers is an essential element of performance and places pressure on student-artists to look a certain way. Anecdotally, circus artists are generally required to maintain very low body fat percentages, while maintaining a high proportion of muscle mass. Understanding body composition characteristics and their variation through the year is critically important knowledge for the development of optimized training programs and to understand any role that body composition might have in either prevention or as a putative injury induction mechanism.

Daily Hassles

Daily hassles (used synonymously with *challenges* in this thesis) are stress-inducing everyday factors that are common to most people, such as those arising from interpersonal relationships, finances, school, and work[17]. Daily hassles have been shown to influence health and performance in several high-performance settings. In professional first-responders, Larsson et al. found strong associations between daily hassles and psychological burn-out and distress[40]. In a cohort of military personnel, Heron et al. observed that daily hassles were significant predictors of post-deployment depression and posttraumatic stress disorder[16]. And, in a series of studies, Ivarsson et al. reported daily

hassles as a significant predictor of injury in athletes[41–43]. In fact, it has been reported that the cumulative impact of daily life hassles on health and performance may be even greater than the stress produced by major life events, such as a divorce or a move to a new city[44,45].

In professional circus, a handful of studies have been published related to psychological factors and their impact on health and performance. Ross et al. completed semi-structured interviews with four professional circus artists to explore mental skills related to training and performance and found that skills such as confidence and emotional management were considered critical to success[9]. In a 2014 study, Shrier et al. assessed the practicability of a prospective longitudinal study aimed at identifying psychological states as risk factors for injury in professional circus artists. In 2011 Shrier and Hallé reviewed historical data of Cirque du Soleil artists to identify psychological predictors of injuries and concluded that low self-efficacy was the strongest predictor. And, Cayrol et al. explored professional circus artists' experiences of injury and injury management[46]. It is important to note that there are differences between the training environments of professional and developing circus artists (students), including their training and performance schedules, travel requirements, and degree of discipline specialization, to name a few.

Direct extrapolation of findings from studies of professional circus artists to artists in training (and vice versa) should be done so with caution, as supported by the following study. Donahue et al. compared professional circus artists from Cirque du Soleil to student-artists from ENC on various measures of mental, social, and physical health and found significant differences between the groups across measures, including social isolation and

anxiety[8]. Donohue et al. also highlighted the importance of coping resources. In the study, professional artists reported receiving more emotional and informational support than circus student-artists, which may help to explain the increased issues related to social isolation and anxiety in the student-artists[8].

To date, it appears that no published studies have characterized the daily hassles or perceived coping characteristics of circus artists in either professional or amateur environments. Longitudinal assessment of daily hassles and perceived coping in a developing circus artist context would provide insight into the variations of hassles over a training year and allow for relation to key additional psychological measures such as non-specific psychological distress and state anxiety. The inclusion of psychological parameters within a holistic assessment of circus student-artists is essential for the development of a comprehensive training optimization program.

Injury

Extensive research has been conducted in high-performance environments, including sport and the military, to identify the causes[47], rates[48], anatomical locations[49], and treatment strategies of injuries[50]. In professional circus, similar studies have been conducted[51–57].

At the elite amateur level of circus arts, three studies have classified the injuries of circus student-artists. Wanke et al. analyzed the injury data of over 160 student-artists at a European State training school and found the overall risk of injury to be relatively low (0.3

injuries per 1000 training hours) and that less than 10% of all injuries required more than three days off from training[7]. Munro et al. conducted an observational study of injuries at Australia's National Institute of Circus Arts, which, similar to ENC, offers a three-year degree program in circus arts[4]. The authors concluded that discipline-specific differences in injury rate were evident, with acrobats experiencing the highest rate of injury, yet no gender-specific differences were found in overall injury rate[4]. And, Stubbe et al. characterized the injuries of student-artists at the Codarts School of Circus Arts in the Netherlands and reported an overall injury rate of 3.3 injuries per 1000 training hours[58].

At ENC, there was anecdotal evidence of an increase in injury rates following the three-week winter vacation period, which contrasts with the cumulative fatigue hypothesis that is predominant in sport contexts. One study at the professional circus level reported that prolonged breaks (two or more days off) resulted in a paradoxical increase in the rate of injuries post-break to pre-break[51] contrary to a cumulative fatigue hypothesis. To date, no circus-specific study has examined the effect of a vacation period on rate of injury in developing circus artists.

General Aim of Thesis

The aim of this thesis was to perform a longitudinal characterization of sleep and fatigue, body composition, and daily challenges of a cohort of elite circus student-artists. A

secondary aim was to examine injury rates after vacation and the putative factors that could be implicated in the generation of elevated injury rates after a vacation period.

Purpose, Objectives, and Hypotheses of Manuscripts

Manuscript 1: Sleep and fatigue of elite circus student-artists during one year of training

- To conduct a longitudinal examination of sleep and fatigue characteristics over one training year in relation to perceived workload.

    1. Student-artists would exhibit disrupted sleep characteristics similar to their athlete counterparts
    2. The sleep and fatigue scores of the student-artists would covary with perceived training load through the training year

Manuscript 2: Body composition adaptations throughout an elite circus student-artist training season

- To examine body composition adaptations over each of the school's two semesters, the winter holiday break, and over the entire training year in relation to changes in subjective workload, as assessed by RPE. Secondarily, we aimed to characterize body composition based upon sex and discipline. We additionally aimed to perform a preliminary between-group analysis of differences in body composition based upon year in program.

1. Student-artists would gain muscle mass and lose in fat mass during each of the two semesters and over the year.
2. Student-artists would lose muscle mass and gain fat mass during the three-week holiday break.

Manuscript 3: Year-long variation of psychological characteristics of student-artists in an elite circus arts training program

- To characterize the daily hassles (challenges) of elite circus student-artists over one training year, examine the variation in daily challenges throughout the year, and relate daily challenges to additional psychological and health measures including perceived coping, state anxiety, non-specific psychological distress, and fatigue. We additionally aimed to assess if daily challenges, state anxiety, perceived coping, and non-specific psychological distress scores would correlate to measures of sleep.

    1. Daily challenges, state anxiety, and perceived coping scores would vary throughout the training year in conjunction with overall fatigue
    2. Individual daily challenge items (e.g., family relationships) would vary throughout the year
    3. Daily challenge would correlate to state anxiety, perceived coping, and fatigue
    4. Non-specific psychological distress scores would correlate to daily challenges, state anxiety, perceived coping, and fatigue. And, student-artists

would report higher levels of non-specific psychological distress than general populations

Manuscript 4: Putative mechanisms of elevated injury rates after vacation break in elite circus artist students

- To examine injury hazard rates surrounding prolonged vacation and derive putative factors that could be responsible for injuries following a three-week vacation period.

1. There would be elevated injury rates after return from vacation relative to the training year and two semesters
2. There would be deleterious changes in sleep, body composition or daily challenges over the winter vacation.

Overview of Methodology

Experimental Design

A longitudinal, observational, cohort study of circus student-artists at Ecole nationale de cirque in Montreal, Quebec, was deployed for manuscripts 1, 2, and 3. For manuscript 4, injury data was extracted using a combined prospective (2015-16) and retrospective (2008-15) injury database review of the ENC clinical database.

Recruitment and Consent

Invitation to participate was provided through a presentation by the research team to the student body at ENC. The students were provided the study paraphrase and consent form at the first assessment session. All information was made available in English and French. Ethical approval for the study was provided by the Human Research Ethics Board at the University of Manitoba.

Description of Participants & Environment

Ninety-two student-artists (mean age 20.39 ± 2.42 SD), which represented over 90% of the student body of the school, participated in the studies that make up this thesis. ENC is internationally renowned as one of, if not, the best circus schools in the world, routinely placing its student-artists in professional circus companies upon graduation. The school has an intake of just 24-30 students each year, 30% of which come from outside of Canada.

ENC employs over 80 staff to service the 100 student-artists nominally registered in the three-year Diploma of Collegial Studies in Circus Arts program. Semester 1 begins in September and concludes in mid-December. Following a three-week winter break from school, semester 2 officially begins in early January and ends in April. For two weeks each May, student-artists perform two newly created shows in front of live public audiences. During the summer months, while away from ENC, many student-artists work as professional circus artists to maintain their technical and artistic competencies, retain their physical capacities, and maintain a fiscally viable circumstance.

ENC operates five days per week, Monday to Friday, commencing at 8:30 am each day. The program is highly regimented yet tailored to each student-artist's specific circus discipline(s). Student-artists typically complete 10 hours of in-class academic work, in addition to 28 to 32 hours of formal technical and artistic classes, each week. All formal academic, technical, and artistic classes are conducted in French, independent of a student's native language. It is routine for student-artists to also complete supplemental informal technical and artistic training of roughly 10 hours per week. A typical student-artist at ENC will train their technical and artistic elements over 35 hours per week. An example schedule for a student-artist is presented in Appendix 1.

Circus Disciplines

In circus arts, there are five major disciplines; acrobatics, balancing, aerials, manipulation, and clowning. Within each discipline, there is a myriad of sub-disciplines. As an example, within the discipline of acrobatics the following sub-disciplines exist; hand to hand,

contortion, hoop, chair, ladder, Russian bar, Russian swing, Chinese pole, Korean board, teeterboard, trampoline, bicycle, rebound straps, German wheel, and cyr wheel. The student-artists at ENC are required to adopt a primary and often a secondary discipline and are required to innovate exciting new methods of expression; in essence to create new movement repertoire which is distinct from many "artistic sports" and ballet where movement repertoire is mostly fixed. While student-artists are expected to develop performance proficiency in their selected discipline(s), all student-artists must demonstrate competency in **all** related major disciplines. Within a typical 30+ hour training week, only around 9 training hours are designated to their principle specialty resulting in a broad range of movement competencies. At ENC, specialization with diversification of movement repertoire is mandated. This is distinctly different from sport where specialization without diversification is typically fostered.

Measurement Timeline

Student-artists completed the following primary measurements at four strategic points in the scholastic year; September, December, January, and April:

1. Sleep and fatigue
2. Body composition
3. Daily challenges, state anxiety, and perceived coping

Completion of these assessments at four time points provided an opportunity to assess changes between semester 1, semester 2, and the winter vacation period using within-person analysis. The monthly workload of the student-artists was also assessed via rating of perceived exertion (RPE) (see section below for more details).

During the training year assessed, student-artists' injury data was also collated. This was combined with retrospective data from the prior seven years (as part of a larger study) to examine the impact of winter vacation on injury rates.

Primary Measurement Tools

Sleep and Fatigue

Sleep and fatigue metrics were assessed using a modified version of the validated Consensus Sleep Diary[59]. Sleep duration was derived from the recorded times for falling asleep (not time going to bed) and waking. Sleep quality, sleep latency, wakefulness (feeling refreshed upon waking), and fatigue were assessed using ten-point numerical rating scales, whereby a score of 1 indicated a desirable score and 10 indicated an undesirable score. Student-artists were also asked to record their daily napping behavior via a simple yes/no question each day. A more detailed description of the tools and procedures is available in manuscript 1.

Body Composition

Multi-frequency bioelectrical impedance (mfBIA, InBody 230, InBody Co., Ltd.) was used to assess body composition using two frequencies (20 kHz and 100 kHz). mfBIA devices when compared to dual-energy X-ray absorptiometry (DEXA) have shown acceptable correlations for lean soft tissue[60] and fat mass[61] and shown precision in tracking body composition changes over time in athletes[62]. The following metrics were acquired:

- body mass (kg)
- fat mass (kg)
- lean body mass (kg)
- skeletal muscle mass (kg)

The absolute mass values were then scaled to body mass and to height[63]. To derive body mass index (BMI), student-artists' height was measured using a stadiometer (Tanita Corp., Tokyo, Japan). A more detailed description of the tools and procedures is available in manuscript 2.

Daily Hassles (Challenges)

Information regarding the daily challenges of the student-artists was attained via the Circus Daily Challenges Questionnaire (CDCQ), adapted from the validated College Student-Athletes' Life Stress Scale (CSALSS) developed by Lu et al[64]. Sixteen daily challenges relevant to a developing circus artist context were added to the questionnaire following a

consensus process further described in manuscript 3. Each of the sixteen items was assessed using a six-point measurement system modelled from the CSALSS[64]. Two scores were derived for each item; a score for the level (intensity) of the challenge and a score for the self-perceived difficulty to manage the challenge. The level score ranged from 0 (none) to 3 (high) and the management score ranged from 0 (no difficulty) to 2 (high difficulty).

State Anxiety

State anxiety was assessed using a single item, modelled after the validated work of Davey et al.[65]. The item was included as a section within the CDCQ. Student-artists rated their current state of anxiety from 0 (no anxiety) to 4 (high anxiety).

Perceived Coping

Perceived coping was measured using a scale which assessed the student-artists' evaluation of their physical and mental capacity to manage stress (0 = lacks ability to 6 = very good ability) combined with an assessment of their perceived access to coping resources inside and outside of the school (0 = no resources to 3 = very good resources). The four scores were summed to derive a total perceived coping score (0 - 18). The questions related to perceived coping were included as a section within the CDCQ.

Non-Specific Psychological Distress

We utilized the six item Kessler Psychological Distress Scale (K6)[66] to screen for moderate to severe non-specific psychological distress during the December time period. K6 scores between 8 and 12 were designated to indicate moderate psychological distress, while severe psychological distress was designated by scores equal to or greater than 13[67]. As the K6 also probes feelings about the previous thirty days, it was additionally used to derive the frequency of negative feelings/emotions, the number of training hours lost due to negative feelings/emotions, how often physical health problems were the cause of negative feelings/emotions, and the total number of doctor visits.

Additional Measurement Tools

Injury

All injuries were recorded via the in-house athletic therapy clinic. Cardiorespiratory, musculoskeletal, and neurological injuries were recorded and classified by location, type, duration, severity, mechanism, and treatment of the injury. Within the clinic, injuries were immediately logged in an injury journal by athletic therapy staff. At the end of each week, the injury journal was compiled and transferred to a research injury database. Given that this was a cohort study, we computed the injury hazard ratio (frequency/unit of time) and expressed it as the number of injuries per week to highlight temporal changes in injury. We calculated the 95% confidence interval for the mean weekly hazard ratio using combined data from the retrospective and prospective database review.

Training Load

Training load was assessed as part of an additional study using a ten-point RPE scale simultaneously with biometrics (Hexoskin, Carre Technologies Inc, Montreal, Canada). Since the student-artists completed multiple training sessions each day, daily RPE scores were derived by averaging the day's multiple sessional RPE scores. For the purposes of the current study, weekly RPE scores were derived by averaging the daily RPE scores within the respective week and then averaged over the month to give a monthly training load. Biometric data is not reported within this thesis.

Body Morphology

Though not included within the present thesis, at all four time points we additionally collected three-dimensional body morphology data on the student-artists using a "structured light" scanner (Structure Sensor, Occipital, V2.0). The data acquisition was controlled by external software (Skanect, v1.6). A predesigned pattern of infrared light was projected from the scanner onto the student-artist being scanned. The deformation of the predesigned pattern caused by the structure of the student-artist was analyzed by the scanner's built-in camera. The distance to each point of the projected grid was derived to reconstruct the three-dimensional surface topology of the student-artist. The scanning process lasted approximately ninety seconds. The scan files were then post-processed (Skanect, v1.6) and virtually dissected (MeshLab, v1.3.3).

Overview of Statistics

A longitudinal, observation cohort study was deployed to allow for within-subject analyses of key parameters. Repeated measures ANOVA was performed with Tukey's post-hoc comparisons. Between-group analysis was undertaken to examine differences between sexes (independent t-tests), differences between disciplines (ANOVA), and differences between years in training program (ANOVA). For all non-parametric measures, Spearman correlation was used. For manuscript 3, Friedman tests with Durbin-Conover pairwise comparison were used for non-parametric data. For specific statistical approaches please refer to the included manuscripts.

Results

Overview

The results of the thesis research are presented in manuscript style. The following four manuscripts are included:

Manuscript 1: Sleep and fatigue of elite circus student-artists during one year of training

- **Authors**: Decker, A., Aubertin, P., & Kriellaars, D.
- **Status**: Published in Medical Problems of Performing Artists*. 2019.* Volume 34 (3). 125 – 131.

- **Contribution**: I was principally responsible for the study design, data collection and analysis, interpretation of results, writing of the manuscript's first draft, and final submission of the manuscript to Medical Problems of Performing Artists.

Manuscript 2: Body composition adaptations throughout an elite circus student-artist training season

- **Authors:** Decker, A., Aubertin, P., & Kriellaars, D.
- **Status:** Accepted for publication in Journal of Dance Medicine and Science (2020)
- **Contribution:** I was principally responsible for the study design, data collection and analysis, interpretation of results, writing of the manuscript's first draft, and final submission of the manuscript to Journal of Dance Medicine and Science.

Manuscript 3: Year-long variation of psychological characteristics of student-artists in an elite circus arts training program

- **Authors:** Decker, A., Cairney, J., Jefferies, P., Aubertin, P., & Kriellaars, D.
- **Status:** In preparation for submission to Work and Stress
- **Contribution of Authors:** I was principally responsible for the study design, data collection and analysis, interpretation of results, and writing of the manuscript's first draft. This version is the final internal review manuscript prior to submission in Summer 2020.

Manuscript 4: Putative mechanisms of elevated injury rates after vacation break in elite circus artist students

- **Authors:** Decker, A., Stuckey, M., Fleet, R., Aubertin, P., & Kriellaars, D.

- **Status:** Accepted book chapter in Circus Medicine (publication in 2020)
- **Contribution of Authors:** I collected the data for the analysis aspect of this book chapter. I was also principally responsible for the generation of the putative mechanisms section.

Manuscript 1: Sleep and fatigue of elite circus student-artists during one year of training

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Published in Medical Problems of Performing Artists

Sleep and Fatigue of Elite Circus Student-Artists During One Year of Training

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Abstract

Aims: The development of elite circus artists requires extensive technical and artistic training, and a commensurate level of physical preparation in readiness for a demanding professional career as a performance artist. While sport research has identified the importance of monitoring sleep and fatigue in athletes to optimize performance, as well as to prevent illness and injury, not a single study of circus artists exists. This study provides a longitudinal examination of sleep and fatigue in elite circus student-artists. **Methods:** 92 student artists (60 male, 32 female) were analyzed at four strategic time points over a preparatory year. At each time point, sleep parameters (duration, quality and latency), ratings of perceived exertion (RPE), wakefulness, and fatigue were obtained using questionnaires. **Results:** Student-artists attained an average nightly sleep of 8 hours and 27 minutes, exceeding the recommended durations for general populations and those self-reported in athletes. The majority of the artists also indicated acceptable sleep latency (87%) and quality (83%) scores. Sleep parameters remained consistent throughout the year despite significant variations in training load and fatigue. Sleep parameters were not substantial predictors of overall fatigue. Fatigue covaried with yearly variation in sessional training loads. **Conclusions:** Although improvement in sleep could be postulated as a means to mitigate fatigue, it is likely that strategies aimed at optimizing the loading profile and additional recovery techniques be a first line approach.

Keywords: recovery; overtraining; periodization; performing arts

INTRODUCTION

Public interest in modern circus has grown immensely over the past few decades, showcased by the existence of over 600 circus training facilities in over 50 countries around the world[1]. Circus artists perform physically and mentally-demanding acrobatic, aerial, equilibrium, manipulation, and clowning skills, each requiring a combination of strength, agility, precision, power, and artistic expression[2,3]. In addition to hours of daily training, depending on the professional company to which they belong, artists may complete 350 or more performances in a year, often with multiple performances in a day[3]. In a study examining the injury rates of athletes transitioning to professional circus, it was revealed that the artists trained, on average, over 8 hours per day, 5 days per week, in a typical 4-month training period[2]. Circus student-artists are similar to their professional counterparts in that their daily training also calls for many hours of technical and artistic training with corresponding physical and mental demands, yet they also have the additional requirement of academic study[4].

Given the demands placed on circus student-artists, coaches and support staff must strike a balance between training load and recovery, as failure to do so, could, as demonstrated in athletes, lead to a state of excessive fatigue known in the sport world as overtraining[5]. Athletes in an over-fatigued state have demonstrated long-term impairments in performance, as well as mental and physical well-being[6,7].

Sport research has identified sleep as a contributing factor in athletes' overall fatigue and a critical component in daily recovery[8,9]. A 2016 systematic review by Gupta et al. concluded that participation in elite sport diminishes sleep quality, evidenced by high rates of insomnia symptoms in athlete populations[10]. Compromised sleep has been shown to adversely affect health[11], increase risk of injury[12], and impair athletic performance[13–16.] Optimized sleep may be of even greater importance to

athletes experiencing high training loads, as they are more likely to experience altered sleep architecture, diminished recovery, and are at an increased risk of overtraining[17,18].

Although athlete-centered research has elucidated the importance of sleep hygiene in fatigue management, the unique physical demands, artistic requirements, and culture within circus makes extrapolation of sport-specific findings to circus artists uncertain[4] and, to date, no circus-specific studies have been conducted. Thus, the principal aim of this study was to undertake the first longitudinal examination of the sleep and fatigue characteristics of elite circus student-artists. Based upon athlete-centered research, we hypothesized that: (1) circus student-artists would exhibit similar sleep characteristics to their athlete counterparts and (2) the sleep and fatigue scores of the circus student-artists would covary throughout the training year based on training load[19,20].

METHODS

Experimental Approach to the Problem

A repeated measures design was used, with collection at four time periods strategically placed throughout the school year; September (commencement after summer break), December (end of term, immediately prior to interim examinations for technical, physical, and artistic proficiency), January (return from winter break) and April (end of term, immediately prior to summative examinations and performances).

Participants' sleep was assessed using a sleep survey modified from the Consensus Sleep Diary[21]. Fatigue, wakefulness and ratings of perceived exertion (RPE) were assessed using 10-point numerical rating scales.

Subjects & Training Environment

Data collection occurred exclusively at Ecole nationale de cirque (ENC). 60 male and 32 female circus student-artists (90% of students in program) participated in the study (Table 1). All five circus families were represented in this study; Clowning (n=3), Manipulation (n=9), Equilibrium (n=12), Aerials (n=37), and Acrobatics (n=31). Students provided informed consent prior to participation in the study. Ethical approval for the study was provided by the Human Research Ethics Board at the University of Manitoba.

The highly competitive, three-year intensive program at ENC leads to a completion of a Diploma of Collegial Studies in Circus Arts. The school has an intake of 24-29 students each year from across the globe (30% outside of Canada). While the school has dormitories available for the student-artists, more than 95% of the students live off-campus. The academic calendar of ENC is similar to that of a typical Canadian college or university, with classes beginning in early September and ending in May/June, with a three-week winter break from school in December. It is worth noting, however, that the month of May is devoted to the creation of two school-wide circus shows which are, once fully developed, performed in front of live public audiences for two weeks. During the summer and winter breaks, the students aim to prevent detraining in technical and physical capacities via the use of self-directed programs (albeit with a substantially reduced time commitment). Moreover, during the summer break, many students work professionally as circus artists.

During the academic year, ENC students complete, on average, 10 hours of in-class scholarly study each week. All classes are conducted in French, independent of a student's first language. The average weekly training, combining technical, physical and artistic categories, exceeds 30 hours per week, with 8-10 hours spent on physical preparation (flexibility, movement preparation, conditioning,

strength training, core), 17 hours on technical training (acrobatics, aerials, dance, manipulation, and equilibrium) of which 9 hours are in the student's specialty, and 5 -12 hours on artistic/creative training. As the school year progresses, the technical, physical and artistic requirements within each training component increase, and continue to increase with each successive year in the program. The school program operates 5 days a week, commencing at 8:30 am each day, and the daily schedule is highly regimented, yet individually tailored to each student's specific circus discipline. Each student has a head coach and an artistic counsellor, and any absence from the program is evident on a daily basis. Students also complete private supplemental training sessions based on their primary and secondary specializations in circus ranging up to 10 hours per week. A total training volume (including in-school training and out-of-school training, excluding academics) ranges from 40 to 49 hours per week. The overall weekly and yearly training hours of elite circus student-artists exceed those reported in studies of elite athletes[22,23].

Procedures

Each morning, for seven consecutive days, during each of four pre-selected time points, the student-artists completed the sleep, fatigue and wakefulness questionnaires. Sleep duration (hours) was derived from the recorded times for falling asleep and waking. Student-artists were specifically advised to record the time they fell asleep as opposed to the time they went to bed. Sleep latency (difficulty falling asleep, 1 = easy to 10 = difficult), sleep quality (overall quality of sleep, 1 = excellent to 10 = poor), wakefulness (how refreshed upon waking, 1 = refreshed to 10 = not refreshed), and fatigue (overall mental and physical fatigue level, 1 = little to 10 = exhausted) were assessed using 10-point numerical rating scales. Weekly napping behaviour was also recorded (# of naps).

RPE scores were collected as part of a larger study on student-artist training load which used a 10-point sessional rating of perceived exertion (sRPE) scale simultaneously with biometrics for data collection[24]. Since the student-artists completed multiple training sessions each day, daily RPE

scores were derived by averaging sRPE scores. For the purposes of the current study, weekly RPE scores were derived by averaging the daily RPE scores.

Also, as part of a larger study, an assessment of daily life challenges (stresses) experienced in school was performed which included two sleep-specific items. The following items were extracted for the purposes of this study; the perceived level of effort required to obtain good sleep (sleep challenge) was assessed using a 4-point scale (1 = no challenge to 4 = high degree of challenge); and the degree to which the circus student- artists had difficulty managing their sleep (sleep management) was assessed on a 3-point scale (0 = no issues managing sleep, 1 = having minor issues, or 2 = having major issues).

Statistical Analyses

Basic descriptive statistics were derived for each parameter. Independent t-tests were used to examine differences in physical characteristics between sexes. Repeated measures ANOVA was undertaken with the effect of time as within-subject, and with two factors modelled as between-subjects (sex and year in program). Tukey's post-hoc comparisons were performed when indicated by significant main effects or interactions. A one-way ANOVA was performed on the year-averaged variables to examine differences between circus families. Single value t-tests were used to compare sleep durations to threshold duration recommendations. Spearman correlations were performed given the categorical nature of most variables. Regression (full model and stepwise) were used to examine associations of sleep parameters with fatigue and wakefulness. SPSS (v23.0) statistical software was used for analysis. Alpha was set at a level of 0.05.

RESULTS

Table 1. Descriptive statistics of the physical characteristics of participants.

	Age (years)	Height (cm)	Mass (kg)	Body Mass Index (BMI)	Body Fat %
Overall	20.90 (2.44)	170.01 (8.01)	66.48 (11.07)	22.85 (2.17)	11.46 (4.83)
Female	20.39 (2.33)	162.11 (5.91)*	56.47 (4.32)*	21.50 (1.26)*	15.93 (3.68)*
Male	21.18 (2.47)	175.01 (5.75)	73.35 (9.37)	23.87 (2.07)	8.85 (2.66)

* $p < 0.001$ difference between sexes.

Table 1 summarizes the physical characteristics of the participants. As expected, female body characteristics were significantly different from males. It is interesting to note that, despite having higher body fat percentages, the BMI of females was significantly lower than males.

Table 2 reports the sleep parameters, wakefulness, RPE, and fatigue scores at each time point along with yearly averages. For all sleep hygiene parameters, there were no significant differences across time points, with only a 16-minute variation in sleep duration over the entire assessment period. However, there were significant fluctuations in fatigue, wakefulness, and RPE ($p < 0.05$). There were no significant effects detected for sex or year in program. Based on yearly-averaged data, there were no significant differences between circus families. Further, we extracted the sleep components of the life challenges survey completed by the students. The students reported a significant increase in the challenge to achieve adequate sleep from September to December ($p = 0.025$). Sleep management trended to decrease (improve) from December to January ($p = 0.068$).

Table 2. Sleep parameters, wakefulness, RPE, and fatigue scores at four times points over the school year (mean, SD) and the overall yearly averages (minimum and maximum, mean, SD)

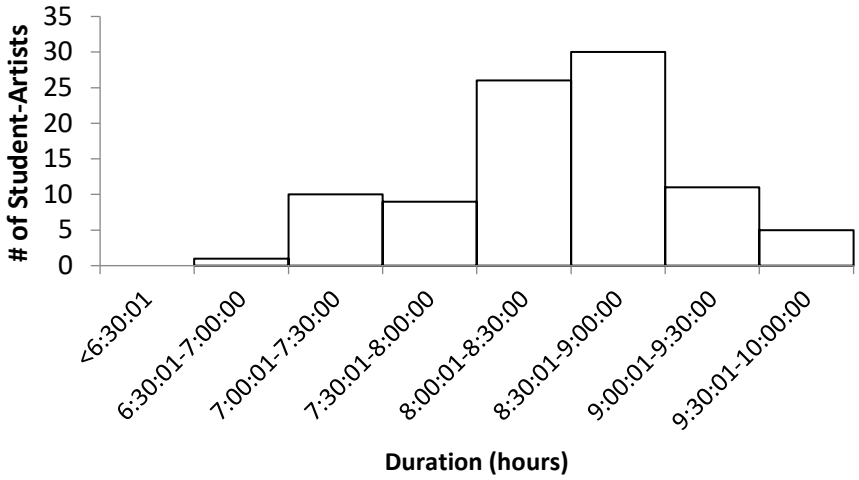
	Time Point				Overall School Year		
	September	**December**	**January**	**April**	**Minimum**	**Maximum**	**Mean**
Sleep Duration (hours)	8:27 (0:59)	8:24 (0:48)	8:36 (1:02)	8:20 (0:44)	6:51	9:48	8:27 (00:40)
Sleep Latency (1-10, easy – difficult)	3.5 (2.00)	3.55 (1.71)	3.22 (1.89)	3.65 (1.98)	1.00	7.83	3.40 (1.55)
Sleep Quality (1-10, excellent – poor)	3.67 (1.66)	3.95 (1.61)	3.54 (1.61)	3.75 (1.53)	1.05	7.14	3.63 (1.36)
Naps per Week (# of naps)	0.57 (1.05)	0.3 (0.71)	0.47 (0.90)	0.69 (1.43)	0.00	6.00	0.53 (0.89)
Wakefulness (1-10, refreshed - not)	4.11* (1.61)	5.11*+ (1.79)	4.29+ (1.66)	4.57# (1.65)	1.64	9.00	4.45 (1.41)
RPE (1-10, easy – difficult)	4.7* (1.54)	7.0*+ (1.89)	5.2+^ (1.56)	6.9^ (1.66)	2.2	8.9	5.95 (1.52)
Fatigue (1-10, little to exhausted)	4.78* (2.16)	5.87*+ (1.86)	4.68+ (2.31)	4.81 (2.16)	1.50	9.50	4.92 (1.72)

* indicates statistically significant variation between September and December ($p < 0.05$) ANOVA, Post-hoc
+ indicates statistically significant variation between December and January ($p < 0.05$) ANOVA, Post-hoc
^ indicates statistically significant variation between January and April ($p < 0.05$) ANOVA, Post-hoc
# - trending 0.1 or less (September to April) ANOVA, Post-hoc

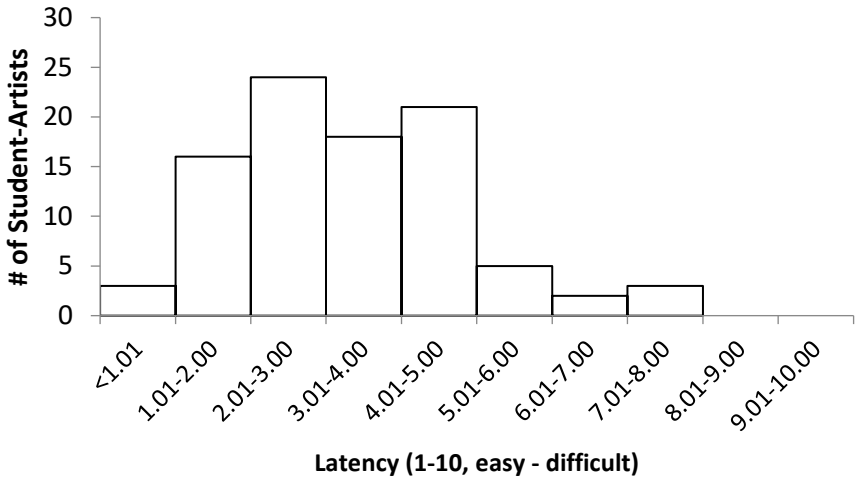
With regard to sleep duration, the student-artists attained an average nightly sleep of 8 hours and 27 minutes (significantly greater than 8 hours, $p < 0.05$; and significantly less than 9 hours, $p < 0.05$). Figure 1 shows the frequency distributions of the yearly-averaged sleep parameters. Evident from the frequency distributions, 21.74% of the students failed to attain a minimum threshold of 8 hours of nightly sleep. Undesirable scores (greater than 5.0) were reported by student-artists for wakefulness (35.9%), sleep quality (17.4%), sleep latency (13%), and fatigue (56.0%).

Figure 1. Histograms of yearly-averaged sleep parameters (A- Duration, B- Latency, C- Quality)

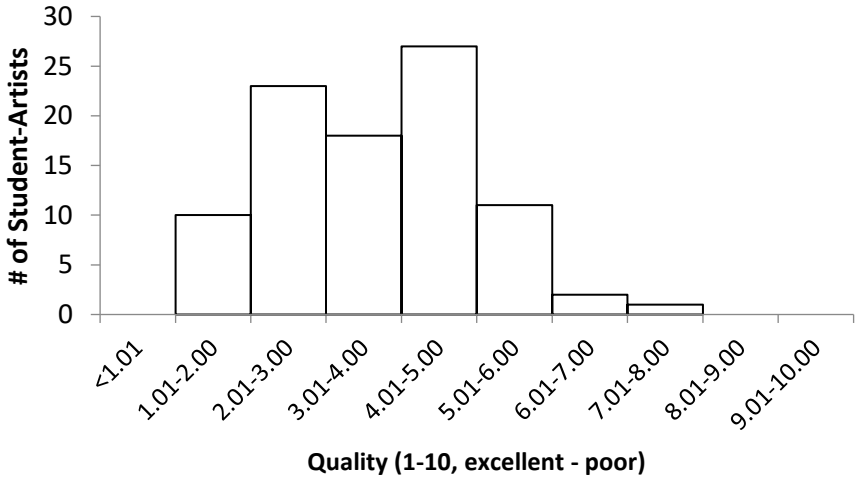
A



B



C



A correlation matrix was derived for sleep, wakefulness, and fatigue (Table 3). Among the sleep parameters (duration, latency, and quality), the only significant correlation was sleep quality with latency. All sleep parameters were correlated to wakefulness ($p < 0.05$), while only sleep quality was related to fatigue. RPE was moderate-strongly correlated to fatigue (r = 0.678, $p < 0.001$).

Table 3. Correlation matrix between sleep hygiene parameters, wakefulness and fatigue (Spearman correlation).

	1	**2**	**3**	**4**	**5**
Duration (1)	-	-0.177	-0.108	-0.263*	-0.196
Quality (2)		-	0.728#	0.606#	0.302*
Latency (3)			-	0.490#	0.223
Wakefulness (4)				-	0.383#
Fatigue (5)					-

*$p < 0.05$
#$p < 0.001$

In order to examine any additive effects of all three sleep parameters, regression (full and stepwise) was performed to predict fatigue or wakefulness. For fatigue, a significant full model was returned (r = 0.342, adjusted $r^2 = 0.087$, $p = 0.012$), while the stepwise regression reduced to a model only including sleep quality (r = 0.304, adjusted $r^2 = 0.082$, $p = 0.003$), consistent with correlation results. For wakefulness, the sleep characteristics accounted for 36% of the variance in wakefulness (r = 0.618, adjusted $r^2 = 0.36$, $p < 0.001$), and identical to fatigue, only sleep quality was returned as a predictive in the stepwise analysis (r = 0.598, adjusted $r^2 = 0.351$, $p < 0.001$).

DISCUSSION

We hypothesized that circus student-artists would exhibit similar sleep characteristics to their athlete counterparts. Contrary to our hypothesis, circus student-artists obtained, on average, longer sleep durations than those self-reported for athlete, non-athlete, and performing artist peers. The circus

student-artists slept an average of 8 hours and 27 minutes each night. Research shows that non-athletes and athletes often fail to reach the recommended values of 8 hours per night for teenagers and healthy adults[25,26] and 9 to 10 hours per night recommended for elite athletes in intense training[27]. In a 2015 survey of over 1,000 American adults, participants self-reported an average nightly sleep of 7 hours and 6 minutes[28]. In athlete self-report studies, sleep durations of 7 hours and 17 minutes (± 56 minutes)[17], 6 hours and 58 minutes (± 1 hour and 2 minutes)[29], and 8 hours and 11 minutes (± 44 minutes)[30] have been reported. Performing artists have also demonstrated suboptimal sleep durations. In a study by Fietze et al., professional ballet dancers self-reported an average sleep duration of 6 hours and 58 minutes (± 43 minutes)[31].

Though the participants in this study, when examined as a whole, achieved the minimum threshold of 8 hours of nightly sleep recommended for healthy adults, when investigated individually, 1 in 5 (21.74%) failed to attain the recommended 8-hour minimum value. Further, when compared against a stricter recommendation of 9 hours (or greater) for elite athletes in intensive training, 82% of the study participants failed to reach this recommended value. We could not conclude which sleep threshold (8 or 9+ hours of nightly sleep) should be used in this population as we did not compare measures of performance between participants who met the recommended sleep guidelines to those who did not. There is evidence from sport, though, that extended sleep duration can impact general performance measures such as accuracy[32] and reaction time[33], which are arguably critical to successful and safe circus artist daily training requirements. Future circus-specific studies should compare sleep duration to performance and recovery measures so that a more accurate sleep duration threshold can be developed.

When we similarly examined the quality and latency scores, we identified that the student-artists, as a whole, attained average scores below the mid-point of the scale throughout the year. Previous studies have reported high rates of sleep quality and latency problems in athlete populations[34,35]. When we reviewed the data on an individual level, though, we found that 17.4% (quality) and 13%

(latency) of the student-artists reported scores above the midpoint of the scale. Given that a cohort of the student-artists individually reported undesirable sleep duration, quality, or latency scores, it appears that, for this population of circus student-artists, individually-directed interventions that target specific deficits in sleep hygiene would likely be more beneficial than general, whole-group, interventions.

Our second hypothesis postulated that the circus student-artists would exhibit similar changes in sleep parameters and fatigue through the training year in response to variations in training load (RPE), as it has been demonstrated that athletes' sleep and fatigue characteristics vary depending on their training loads[17,36] and schedules[37]. As hypothesized, we observed variation in fatigue scores over the year consistent with undulations in training demands. Contrary to hypothesis, and unlike their athlete counterparts, we detected no significant variations in sleep parameters through the year, despite substantial load variations indicated by both RPE scores and the student-artists' pre-planned training schedules. Interesting, too, is the fact that the student-artists' sleep parameters (acceptable scores or not) remained unchanged despite the fact that their perceived level of challenge associated with attaining adequate sleep hygiene statistically increased from September to December and that seasonal variations in sleep duration have been previously reported[38]. This finding likely represents that the students made concerted efforts to maintain their sleep patterns despite the elevated work load (evidenced by RPE) leading into December and the performance and evaluation stresses of December examinations. We further suggest that the context in which the circus student-artists train may also somehow mitigate this erosion in sleep hygiene; perhaps owing to the highly structured nature of the school. Further exploration of this "protective effect" is warranted, and points to consideration of differences in the training contexts between amateur athletes and these developing circus performers.

When sleep characteristics were examined at each time point to identify differences between sexes, statistically significant results were not detected. In regards to sleep quality and latency, consensus

has not been reached in previous studies as some authors have reported better sleep latency and quality scores in females[39,40], while others report better scores in males[41,42]. Of note, however, is a study of professional ballet dancers by Fietze et al. wherein the authors assessed sleep duration, latency, and quality and found no differences between sexes; mirroring the results from the present study[31].

The fact that the student-artists were able to maintain threshold recommendations for sleep duration (> 8 hours) and overall sleep quality and latency scores below 4 out of 10 throughout the year suggest, at first-glance, that the student-artists attained acceptable sleep. However, their sleep may, in fact, have been insufficient as the student-artists were unable to prevent the accumulation of fatigue during periods of high training loads. For example, the student-artists fatigue scores increased from 4.78 in September to 5.87 in December (Table 2). As well, the student-artists averaged fatigue scores near the mid-point of the scale (4.92 out of 10) over the entire training year (Table 2). Further still, when we examined the data on an individual basis, we found that 35.9% and 56% of the student-artists reported wakefulness and fatigue scores, respectively, above the midpoint of the scales. These findings indicate that student-artists carried with them relatively high fatigue levels over the training year and that their recovery practices were insufficient to combat training-induced fatigue.

Given the fatigue scores of the student-artists, we explored if sleep parameters could substantially predict fatigue. When we performed the regression analysis, however, we found that less than 9% of fatigue variance was accounted for by sleep parameters, alone. Alternatively, correlation analysis revealed a moderately-strong relationship between training load (RPE) and fatigue. Additionally, as hypothesized, statistically significant differences were detected for fatigue and wakefulness that were consistent with the RPE and training schedules of the students between September and December and between December and January. Student-artists reported the highest levels of fatigue and felt the least refreshed upon waking in the months of December and April while

preparing for technical and academic examinations. This finding is likely explained by both an accumulation of training load over the semester (as indicated by RPE scores) and the elevated psychological stress associated with midterm examinations[43]. These results indicate that, while the sleep of the student-artists may have been inadequate, it is unlikely that sleep was the sole cause for the elevated levels of fatigue experienced by the student-artists and that the high training loads of the student-artists were, perhaps, a more substantial contributor. This finding supports previous research that shows that fatigue is a multifactorial construct[44] and additional factors, such as training load, warrant monitoring.

Finally, the lowest levels of fatigue and best wakefulness scores were reported in September and January following the summer and winter breaks. This finding is important as it suggests that training loads may need to be reduced in advance of academic examinations and that the scheduled breaks in the academic calendar (summer and winter holidays) offer the student-artists a modest level of reprieve from the high training and academic demands of the school. This finding aligns well with recommendations made in studies on athletes and dancers to provide participants with extended "time-off" at designated points in the yearly training plan to, primarily, prevent overtraining and injuries[6,45]. While the student-artists did return from break in a more recovered state, it was disconcerting that their levels of fatigue were still close to the midpoint of the 10-point scale, indicating that their recovery may not have been optimized. Though the optimal level of fatigue for performance upon return from break is unknown, this points to a possible interventional opportunity for staff to aid in the development of optimized rejuvenation strategies during scheduled breaks.

Limitations

An important limitation of this study was the use of sleep logs as opposed to polysomnography or actigraphy. Sleep logs were selected for use in this study as previous studies have shown that they are inexpensive, highly practical, and have internal reliability and validity[46,47]. They are, however,

known to be less precise than actigraphy and polysomnography as they are subject to participant recall[48]. It is possible that our use of a sleep log may have contributed to a failure to detect sleep parameter changes throughout the academic year. This possibility is mitigated, however, due to the fact that additional parameters (fatigue, wakefulness, RPE), using similar tools, revealed changes between time points. Future circus-specific sleep studies should use actigraphy or polysomnography to assess sleep, when available. The conclusions of this study are limited to developing circus artists, and as such, extrapolation of the results to professional performers is likely not warranted given the substantive differences in performance schedules and travel requirements for performers in non-resident shows. A strength of this study was that we were able to successfully implement multiple assessments throughout the training year in order to investigate the associations between sleep and fatigue.

CONCLUSIONS

Circus artists are appreciated around the world for their entertaining and artistic feats, yet, from a research point of view, a limited amount is known about this unique and growing population. This study offers coaches and practitioners a novel exploration into the training environment of elite circus and the sleep and fatigue characteristics of circus student-artists in this context.

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Manuscript 2: Body composition adaptations throughout an elite circus student-artist training season

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Body composition adaptations throughout an elite circus student-artist training season

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ABSTRACT

The purpose was to perform a longitudinal assessment of body composition of circus student-artists in an elite three-year college training program. Ninety-two student-artists (age = 20.39 ± 2.42, height = 170.01 ± 8.01 cm, mass = 66.48 ± 11.07 kg, 36% female and 64% male) participated, representing 92% of the total student population. Body composition was assessed using multi-frequency bioelectrical impedance (mfBIA, InBody 230, InBody Co., Ltd.) at four strategic time points throughout the training year to evaluate changes over the two semesters (September to December; January to April) and winter vacation (December to January). Workloads were subjectively assessed using ratings of perceived exertion (RPE). Averaged over the scholastic terms, fat mass was 11.5 ± 4.8%, muscle mass was 50.2 ± 3.4%, and body mass index was 22.9 +/- 2.2. Male and female student-artists differed significantly across all absolute and relative body composition variables. Muscle mass increased (semester one, +1.0%, $p < 0.001$; semester two, +0.4%, $p < 0.05$) while fat mass decreased during each semester (semester one, -1.6%, $p < 0.001$; semester two, -0.6%, $p < 0.05$) covarying with changes in RPE (semester one, +2.3, $p < 0.05$; semester two, +1.7, $p < 0.05$). During the winter vacation period, percent fat mass increased (males, +1.0%; females, +2.0%) and percent muscle mass decreased (males, -0.6%; females, -0.9%). Discipline-specific differences in body composition were also detected. Significant differences were observed between student-artists grouped by years in school. Over the training year there was a positive adaptation for muscle and fat mass despite the negative adaptation experienced over the winter vacation period.

Key Words: muscle mass, fat mass, lean mass, performers

INTRODUCTION

Research in athletes and dancers has shown that effectively monitored body composition measurements can be used to predict performance[1,2,] benchmark development[3,4,] identify potential talent[5,6], and can be used to select playing positions within specific sports[7]. For activities in which relative strength and power, thermoregulation, or aerodynamics are emphasized, the attainment of optimal body composition measurements may be of even greater importance[8]. In several sports (e.g., figure-skating) and performing arts (e.g., ballet), body composition goals are driven not only by function and performance, but additionally by aesthetics. This is similarly true for elite performance in circus arts.

To prepare developing circus artists for life in the professional ranks, circus student-artists' bodies must be able to endure demanding physical, artistic, and technical training[9], pliable enough to attain extreme ranges of motion[10], and delicate enough to express emotion and make connections with audience members using non-verbal communication[11]. Given these demands, a characterization of circus student-artists' body composition is warranted, yet no such evaluations have been published, to date.

Studies from sport have demonstrated the importance of measuring body composition and doing so with respect to sex and adaptations over time[12]. Vercruyssen et al. assessed the body composition of collegiate gymnasts via skinfold measurements during the pre-, mid-, and post-season and found that the gymnasts' body weight decreased between the pre- and mid-season, their percent fat mass (FM) decreased across all time points, and their lean mass (LM) remained unchanged over the season[13]. Micheli et al. evaluated the changes in body composition of male and female professional dancers between the pre- and post-season of a ballet season via skinfold measurements and noted no significant changes for the male performers, yet significant decreases in body mass and percent FM in the females[14]. And, in a study by Minett et al. using dual-energy X-ray absorptiometry (DEXA),

female collegiate soccer players (non-starters) decreased their LM values over the season and gained FM over the offseason[15]. The results of these studies indicate that body composition changes can occur in high performance settings. A similar examination of body composition changes throughout a circus training season would provide valuable insight into the within-season training responses and nutritional requirements of circus student-artists.

Studies have also examined the differences in body composition in athletes relative to years in program[16,17]. In one example, Fields et al. assessed longitudinal changes in body composition in over 300 male and female college basketball athletes[18]. Between years in program, freshmen male athletes reported higher fat-free mass than sophomores, while female sophomores recorded higher fat-free mass than junior athletes[18]. No statistically significant differences were observed for FM or percent FM. In a study of forty-two collegiate basketball players, Hunter et al. reported significant differences in body weight and LM between freshmen and sophomores and between junior and senior athletes[16]. The authors noted a 7.5 kg difference in body weight and a 6.5 kg difference in LM between freshmen and senior athletes, with no significant difference in FM between year-groups[16]. Both sport-based studies reveal body composition differences between student-athletes with respect to years in program. The study by Hunter et al. demonstrated a positive progression in LM with increased program experience consistent with the cumulative benefits of training[16]. A comparison of student-artists with respect to years in program would provide valuable insight into the body composition changes experienced over time during a professional preparatory program.

Several factors contribute to changes in body composition over time[19]. One such factor is training load[20] (or workload), which is generally subdivided into internal and external training load and can be assessed using several different methods related to the volume and intensity of training[21]. One commonly used method to assess the intensity component of workload is subjective rating of perceived exertion (RPE)[22]. Across a variety of training modalities, appropriately increased training demands resulted in desirable body composition adaptations[6,23,24]. Substantial reductions in

workload have elicited undesirable changes in body composition. Studies of female collegiate dancers[25], male professional soccer players[26], and male and female collegiate swimmers[27] have shown increased measures of FM in response to eight-week, six-week, and four-week detraining periods, respectively. LaForgia et al. reported significantly reduced fat-free mass in trained male athletes after only a 3-week break from regular training[28]. The relationship between training load and body composition is further highlighted in a study by Cadegiani et al. in which the authors reported increased FM, as well as decreased muscle mass (MM) and basal metabolic rate in over-trained athletes compared to healthy athletes[29]. It has been reported that circus student-artists in elite training schools perform, on average, over forty hours of in- and out-of-school physical, artistic, and technical training each week with fluctuations in workload throughout the year in a wide variety of disciplines beyond their primary speciality[9]. Given the unique training demands experienced by elite circus student-artists over a training year[9], it is worth investigating body composition adaptations to these high and varied training loads.

To date, there is an absence of research tracking body composition in circus student-artists. Circus student-artists' yearly training is typically divided into two academic semesters, separated by a winter holiday break. A characterization of body composition adaptations through these time periods and over an entire training year would provide valuable information to assess program efficacy. Such research would be foundational to aid in the development of performance science, performance medicine, and technical and artistic personnel to elucidate periods of high and low training load within the training year and offer valuable insight to optimize physical preparation, psychological, nutritional, and recovery interventions and strategies.

The primary purpose was to employ a longitudinal cohort design to examine body composition adaptations over each of the school's two semesters, the winter holiday break, and over the entire training year in relation to changes in subjective workload, as assessed by RPE. We hypothesized a gain in MM and loss in FM during each of the two semesters and over the year. We also

hypothesized that student-artists would lose MM and gain FM during the three-week holiday break. Secondarily, we aimed to characterize body composition based upon sex and discipline. We additionally aimed to perform a preliminary between-group analysis of differences in body composition based upon year in program.

MATERIALS & METHODS

Experimental Design & Participants

Ninety-two student-artists (mean age 20.39 ± 2.42, 36% female and 64% male) from Ecole nationale de cirque (ENC) in Montreal, Quebec, Canada, participated in the study. The primary aim of ENC is to develop the technical and artistic abilities of the student-artists for a career in professional circus. This is achieved through a rigorous three-year college program during which students also complete academic coursework. Prior to formally entering the program, a select group of students participate in a preparatory year. The students were grouped into four categories based upon the year in program (year one to three) for those formally enrolled in the professional program, and year zero for those enrolled in the preparatory program. For a detailed description of the school and its development program, please see Decker et al[9]. The student-artists' body compositions were assessed at the beginning and end of each of the school's two semesters. Following the conclusion of the first semester (December) and prior to the commencement of second semester (January), the student-artists were given a three-week vacation. Ethical approval for the study was provided by the Human Research Ethics Board at the University of Manitoba, and informed written consent was obtained prior to participation.

Tools & Procedures

Body composition was assessed using multi-frequency bioelectrical impedance (mfBIA, InBody 230, InBody Co., Ltd.). Compared to skinfold thickness and single-frequency bioelectrical impedance analysis, mfBIA devices have shown to be reliable[30] and accurate[31], respectively. When compared to

near gold standard techniques, such as DEXA, mfBIA devices are generally more affordable and accessible, and have shown acceptable correlations for lean tissue[32] and FM[33]. Body mass (kg), FM (kg), LM (kg), and MM (kg) were derived. The absolute mass values were then scaled to body mass and to height[34]. Student-artists' height was measured using a stadiometer (Tanita Corp., Tokyo, Japan) for height normalization.

At the time of each body composition assessment, the student-artists were instructed to remove all footwear (only bare feet were permitted), wear minimal clothing, and remove all metals (e.g., earrings) from their body. Student-artists were also advised to avoid eating and drinking (except for small amounts of water) for three hours prior to the assessment. All tests were conducted in the morning. At each time point, the data was exported to a CSV file and input to a spreadsheet.

The intensity component of workload was assessed via RPE, which is a commonly-used, reliable, and practical measure of subjective workload[35]. The RPE scores were collected using a 10-point scale[36]. The student-artists completed several training sessions each day and for each session provided an RPE score. For each day, a daily RPE score was derived by averaging the day's multiple RPE scores. Weekly RPE scores were then derived by averaging daily RPE scores. For this study, we did not employ an objective measure of workload such as heart rate or accelerometry. Despite this limitation, RPE has been shown to have a moderate to strong relationship to objective measures and is commonly used by major organizations[37].

Statistical Analyses

Independent t-tests were used to examine differences in body composition between sexes. ANOVA was performed to evaluate differences between circus disciplines and program year. A within-subject, repeated measures ANOVA was used to assess differences between time points in the scholastic year. Pearson correlation coefficients were derived between selected body composition variables. SPSS (v23.0) statistical software was used for analysis. Alpha was set at a level of 0.05.

RESULTS

Characterization of Body Composition

Table 1 reports yearly-averaged descriptive statistics for body composition for all student-artists and by sex. Despite females carrying more FM (absolute and relative) than males ($p < 0.01$), females had a statistically lower body mass index (BMI). Using the standard BMI scale[38], 28% of the male student-artists were classified as overweight. The “overweight” classification arose from high proportions of MM and not from FM (Table 1). In male student-artists’ MM more strongly correlated than FM to BMI (r = 0.71 versus r = 0.52, respectively). Females carried slightly over 7% more FM than males, and their FM (r = 0.50, $p < 0.01$) was more strongly correlated than MM (r = 0.04, not significant) to BMI.

Table 1. Descriptive statistics for key body composition variables (mean, SD)

	All	Female	Male
Height (cm)	170.0 (8.0)	162.6 (5.5)*	174.3 (5.8)
Mass (kg)	66.5 (11.1)	56.3 (4.4)*	72.2 (9.6)
Fat			
FM (kg)	7.4 (2.8)	9.1 (2.6)*	6.5 (2.5)
FM (%)	11.5 (4.8)	16.2 (4.3)*	8.9 (2.8)
FM (kg/ht^2)	2.6 (1.1)	3.5 (1.1)*	2.1 (0.8)
Lean Tissue			
LM (kg)	59.0 (11.2)	47.2 (3.9)*	65.6 (8.2)
LM (%)	88.5 (4.8)	83.9 (4.3)*	91.1 (2.8)
LM (kg/ht^2)	20.2 (2.3)	17.8 (0.9)*	21.5 (1.7)
Muscle			
MM (kg)	33.5 (6.9)	26.2 (2.4)*	37.6 (5.0)
MM (%)	50.2 (3.4)	46.5 (2.6)*	52.2 (1.7)
MM (kg/ht^2)	11.5 (1.5)	9.9 (0.6)*	12.3 (1.1)
BMI	22.9 (2.2)	21.3 (1.4)*	23.7 (2.1)

**statistically significant difference between females and males ($p < 0.001$)*

Table 2 reports the descriptive statistics (mean, SD) for body composition by circus discipline and sex. Statistically significant differences were found between sexes for all disciplines when we compared males to females from matched disciplines ($p < 0.05$). Sex-matched comparisons between disciplines also yielded statistically significant results ($p < 0.05$). In males, no statistically significant differences were observed for percent MM between disciplines, yet for percent FM, student-artists in the clown/manipulation group differed from all other disciplines. In females, the aerialists were found to higher percent MM and lower percent FM than all other disciplines.

Table 2. Mean (SD) values of key body composition variables by circus discipline and sex

	FEMALE					MALE				
	Base	**Acrobatics**	**Aerial**	**Equilibrium**	**Manipulation & Clown**	**Base**	**Acrobatics**	**Aerial**	**Equilibrium**	**Manipulation & Clown**
Height (cm)	-	157.9 (5.7)	164.3 (5.2)+	159.1 (5.9)^	161.7 (4.7)+	179.3 (3.2)	171.6 (5.8)*	170.9 (4.4)*	174.3 (7.6)*	175.8 (4.1)*^
Body Mass (kg)	-	55.0 (6.3)	56.9 (4.1)	55.8 (5.5)	56.8 (4.0)	85.4 (4.3)	69.6 (6.8)*	64.7 (6.6)*	69.2 (5.6)*	75.6 (10.3)*^
Fat										
FM (kg)	-	10.2 (3.0)	8.4 (2.1)	11.5 (3.0)^	12.2 (2.1)^	8.2 (2.4)	6.2 (1.9)*	5.2 (1.0)*	5.9 (2.5)*	8.5 (3.7)+^$
FM (%)	-	18.5 (5.0)	14.6 (3.3)+	20.4 (3.3)^	21.5 (3.1)^	9.6 (2.6)	8.9 (2.2)	8.1 (1.4)	8.6 (3.4)	11.1 (4.2)*+^$
FM (ht^2)	-	4.1 (1.2)	3.1 (0.8)+	4.5 (0.8)^	4.7 (0.6)^	2.6 (0.8)	2.1 (0.6)	1.8 (0.4)*	2.0 (0.9)*	2.7 (1.1)+^$
Muscle										
MM (kg)	-	24.9 (3.3)	27.0 (2.1)+	24.5 (1.5)^	24.7 (1.3)^	44.7 (2.1)	36.3 (3.6)*	33.8 (3.8)*	36.1 (3.1)*	38.5 (5.5)*
MM (%)	-	45.1 (3.1)	47.4 (1.9)+	44.0 (1.7)^	43.4 (1.4)+^	52.4 (1.5)	52.2 (1.3)	52.3 (1.0)	52.2 (2.0)	50.9 (2.6)
MM (ht^2)	-	9.9 (0.7)	10.0 (0.7)	9.7 (0.2)	9.4 (0.2)+^	13.9 (0.5)	12.3 (0.7)*	11.6 (0.9)*+	11.9 (0.4)*	12.4 (1.2)*^
BMI	-	22.0 (1.2)	21.1 (1.4)	22.0 (0.5)	21.7 (0.5)	26.6 (1.1)	23.6 (1.4)*	22.1 (1.5)*+	22.8 (1.3)*	24.4 (2.2)*^

**statistical significant difference (p < 0.05) to Base*
+ statistical significant difference (p < 0.05) to Acrobatic
^ statistical significant difference (p < 0.05) to Aerial
$ statistical significant difference (p < 0.05) to Equilibrium
 # statistical significant difference (p < 0.05) to Manipulation/Clown

Changes in Body Composition Over Training Year

Table 3 reports the changes in body composition variables and RPE over time. Percent MM covaried with changes in RPE. Percent FM varied inversely. Throughout semester one, 79% of male student-artists and 74% of female student-artists decreased their percent FM, while 85% of males and 78% of females increased their percent MM. Throughout the second semester, 56% of males and 77% of females decreased their percent FM, while 54% of males and 81% of females increased their percent MM.

Table 3. Differences between time points for RPE, FM, and MM

	Semester One	Vacation	Semester Two	Scholastic Year
RPE	+2.3*	-1.8*	+1.7*	-
Fat				
FM (kg)	-0.8 (1.8)**	+1.1 (2.2)**	-0.4 (1.5)*	-0.5 (2.1)**
FM (%)	-1.6 (2.4)**	+1.3 (2.7)**	-0.6 (2.1)*	-1.0 (2.1)**
FM (kg/ht^2)	-0.3 (0.5)**	+0.30 (0.5)**	-0.2 (0.5)*	-0.2 (0.8)**
Muscle				
MM (kg)	+1.3 (0.9)**	-0.7 (0.9)*	+0.40 (0.9)#	+2.0 (6.3)**
MM (%)	+1.0 (1.3)**	-0.7 (1.3)**	+0.4 (1.3)*	+2.6 (9.6)**
MM (kg/ht^2)	+0.4 (0.3)**	-0.1 (0.3)*	+0.1 (0.3)	+0.6 (2.1)**

- indicates a reduction in scores over time
+ indicates an increase in scores over times
** $p < 0.05$,** $p < 0.001$, # trending $p < 0.08$*

Figure 1 highlights the changes in percent FM and percent MM in the student-artists over semester one, where the students are separated into groups based upon their year in program and by sex. This figure illustrates that there are positive adaptations in FM and MM for the student-artists enrolled in all three of years of the formal professional program, independent of sex. The student-

artists grouped into the “year zero” category were provisionally accepted into the school since they demonstrated potential, but were not formally accepted into the professional degree program. Of note, female student-artists in the year zero group gained an average of 1.6% FM (±2.4, $p < 0.05$) and lost 0.8% MM (±1.3, $p < 0.05$) over semester one.

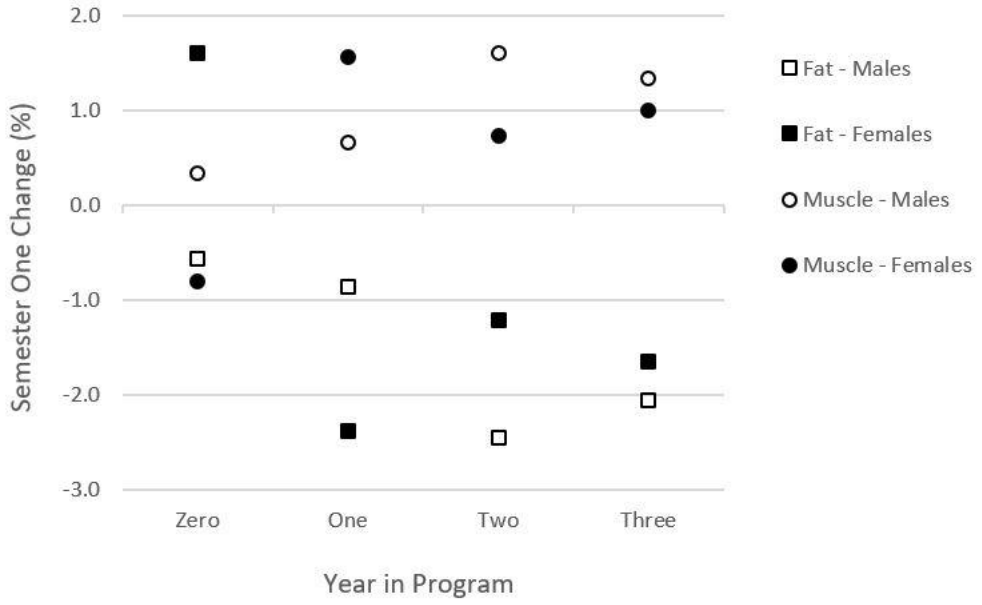

Figure 1. Change in percent FM and percent MM over semester one by year in school and by sex.

Figure 2 shows histograms of the changes in percent FM and percent MM of the student-artists during the three-week vacation between the first and second semesters for males (A) and females (B). Male student-artists, on average, incurred a 0.6% (± 1.3) reduction in MM while gaining 1.0% (± 2.1) FM. Female student-artists lost 0.9% (± 1.2) MM while gaining 2.0% (± 3.4) FM. Over the vacation period, 73% and 70% of all student-artists gained FM and lost MM, respectively.

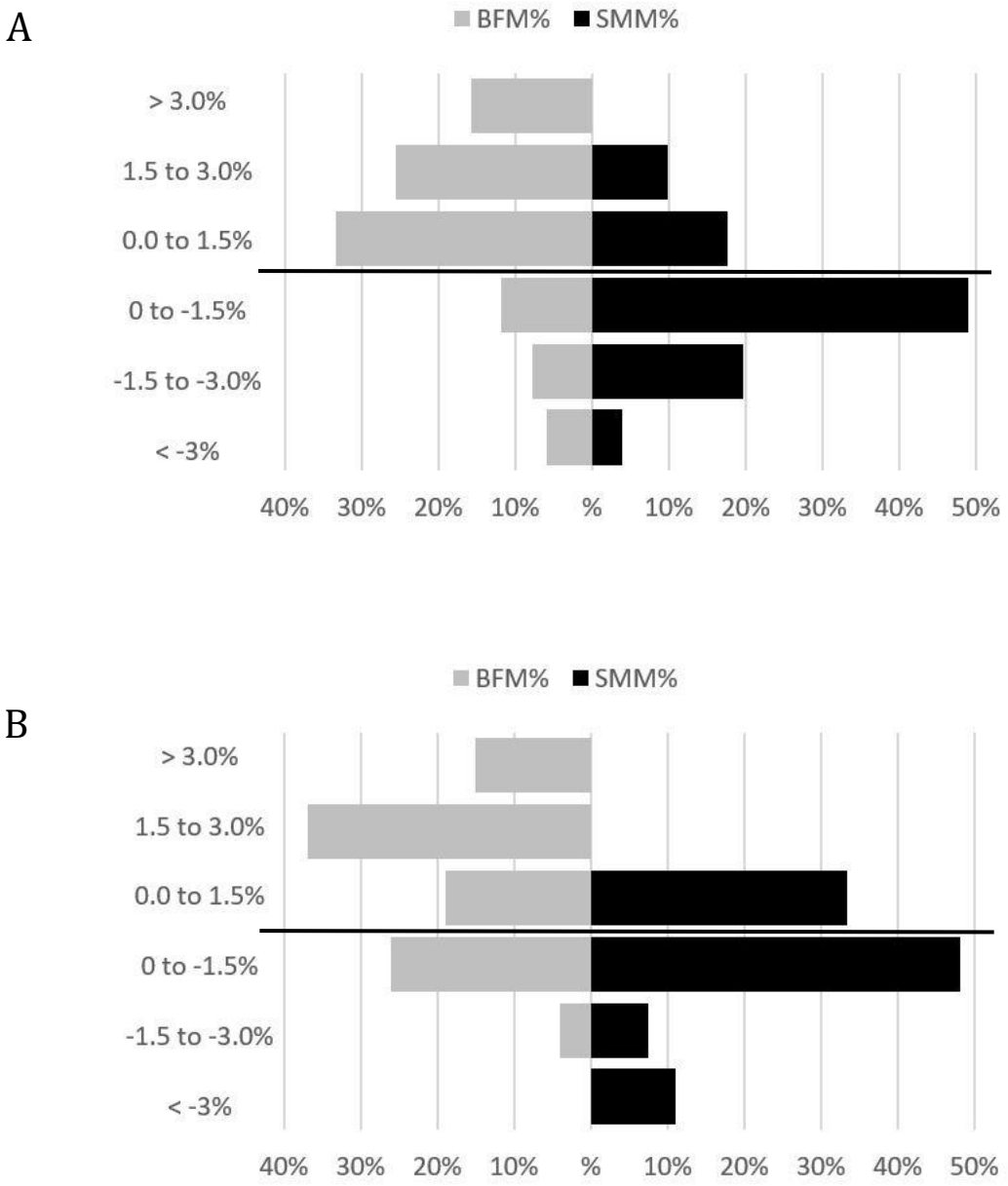

Figure 2. Histogram of change in percent FM and percent MM during vacation in males (A) and females (B)

Differences Based on Years in Program

We undertook an exploratory analysis for differences between groups of student-artists based on year in program and observed statistically significant increases in year-averaged LM (kg/ht^2; $p <$

0.05) and MM (kg/ht^2; $p < 0.05$) between year-groups zero and three. We also observed results trending toward significance in year-averaged LM, MM, and percent MM ($p = 0.05$ to 0.10) between year-group zero and year-groups one and two. As this was a between-subject comparison between years, there was a decreased ability to detect differences with an increased likelihood for type two error.

DISCUSSION

Characterization of Body Composition and Program Efficacy

As a general finding, the results of this study demonstrate that elite circus student-artists were, on average, highly muscular and possessed little body fat (Table 1). For reference, we related the percent FM and percent LM of the student-artists to age-matched athletes and dancers[39–49]. Regarding percent FM, female student-artists (16.2%) reported lower values than female gymnasts (19.7 ± 4.0)[39], taekwondo athletes (23.2 ± 3.58)[40], and ballet dancers (17.4 ± 3.9)[42] (18.4 ± 4.35)[43]. Male student-artists' (8.9%) values were lower than their athletic peers from wrestling (12.8 ± 5.3)[44], taekwondo (11.4 ± 2.38)[40], and professional soccer (11.9 ± 6.2)[45]. Regarding percent LM, female student-artists (83.9%) reported higher values than female gymnasts (72%)[46], soccer players (75%)[47], and ballet dancers (82.2%)[48]. Male student-artists (91.1%) reported higher values than athletes from soccer (82.6%)[45], rugby (81.2%)[49], and skill position players from American football (81.8%)[41]. The lower FM and higher LM values found in circus student-artists may reflect the training volume and diversity required within the professional program, where an increased training volume may account for lower FM values and a diversity of training may account for higher LM values arising from the development of MM throughout the body. Further study is required to examine the FM and LM distributions across body segments in this population and in comparison to athletes.

In agreement with our first hypothesis, the student-artists collectively experienced statistically significant increases in MM and reductions in FM during the two semesters in concert with changes

in RPE (Table 3), which resulted in a net gain of over 2.5% in MM and a net loss of 1.0% FM from the beginning to the end of the scholastic year. We also noted that student-artists experienced less change in their body composition over semester two than in semester one, owing, at least in part, to the smaller increase in RPE experienced over semester two than in semester one (Table 3). During semester two, there was a shift in the school's curriculum from an emphasis on physical preparation and acrobatic development in semester one to artistic development.

Studies from sport examining body composition changes throughout a competitive season have generated mixed results[12,15,50,51]. Milanese et al. noted similar results to ours with an average increase in percent fat-free mass of 1.2% and a decrease in percent FM of nearly 1.0% from pre-season to post-season in professional male soccer players[47]. Conversely, Georgeson et al. assessed male professional rugby athletes via dual-energy x-ray absorptiometry (DEXA) and observed an average decrease in percent LM of approximately 1.5% and no change in percent FM[52]. Direct comparison across studies warrants a degree of caution, however, as the circus student-artists in the present study did not have substantial travel or performance requirements throughout the training year, which differs from many collegiate sport and professional sport and dance programs, and the measurement techniques and participant characteristics vary between the studies.

In agreement with our second hypothesis, the student-artists collectively gained an average of over 1.0% FM and lost 0.7% of their MM over the three-week detraining period in December (Table 3). The increase in FM and concomitant decrease in MM over the extended mid-season break reported in this study is concerning as it could result in; altered biomechanics, particularly during aerial activities; reduced power production of muscle; and expedited onset of fatigue; all of which have potential consequences for performance and injury[53,54]. Though not determined in this study, the mechanisms by which the artists gained FM and lost MM are of interest. While reduced caloric expenditure via a reduction or cessation of training is a logical contributor to the gain in FM and loss

of MM, overconsumption of food, hectic travel schedules, and alcohol consumption are additional plausible culprits that bring with them residual mechanisms for decreased performance, such as dehydration and altered movement patterns. It would be useful for future studies to more closely examine the behaviours of student-artists during extended time-off from training to assist circus coaches and practitioners to better prepare student-artists for periods of reduced training load through education and individualized training and nutrition strategies.

While Table 3 reports the average change in RPE, MM, and FM of the student-artists collectively over the two semesters, the vacation period, and the entire training year, we further explored the results to determine if the variations were evident in all year-groups. As shown in Figure 1, all year-groups showed positive adaptations in line with changes in RPE over semester one, except the female student-artists in year-group zero. This is an interesting finding in that both male and female student-artists experienced reduced training loads compared to student-artists in year-groups one, two, and three, yet only the female student-artists in the preparatory year failed to show positive adaptations over semester one. Future research is required to understand plausible mechanisms through which the female student-artists in year-group zero failed to positively adapt during semester one.

Sex and Discipline-Specific Differences

Our second aim was to characterize body composition based upon sex and circus discipline. Sex-based differences were evident across all body composition variables. Of note, we found that female student-artists carried more absolute FM than their male counterparts. Previous research has elucidated differences in both the amount and the distribution of fat in females versus males[55]. It has been estimated that, when comparing females and males from the general population with identical BMI scores, females will carry approximately 10.0% more FM than their male counterparts attributed to both hormonal and genetic factors[55]. It appears that increased levels of physical activity slightly mitigates this sex-based difference[56]. However, traditional physical education and sport programs

have been shown to provide less training opportunities to females than to males[57,58], so it is possible that differences in physical activity may be an additional factor to explain sex-based differences in FM. Within the population of the present study, we found that female student-artists carried slightly over 7.0% more FM than male student-artists. This is an important finding given the unique training approach at ENC whereby student-artists undertake virtually identical volumes and intensities of training, regardless of their sex. The differences reported in the present study then are likely not due to discrepancies in the demands of the student-artists' training and may more accurately represent the genetic and hormonal sex-based differences sex-based difference in FM.

Regarding discipline-specific differences, studies from sport have observed differences within several sports[18,59,60]. In one example, Ramos-Campo et al. used mfBIA to analyze the differences in body composition by playing position in athletes from three indoor team sports; handball, basketball, and futsal[61]. The athletes were divided into four position groups and were assessed for differences across a range of body composition measures. Statistically significant differences were found between playing positions in all sports. Similar results were observed in the present study. Student-artists differed significantly from one another when grouped based on primary discipline (Table 2). Unlike most traditional sport programs, however, the student-artists at ENC are required to train in all disciplines, not only their primary and secondary disciplines. It was interesting to observe that a more diverse approach to training did not mask discipline-specific differences when adjusted for height and body mass.

Differences Based on Years in Program

As an additional aim, we examined the body composition differences between student-artists based on years in program. We observed statistically significant differences between groups for two variables; LM (kg/ht2) and MM (kg/ht2). Given that we found results trending toward significance in LM, MM, and percent MM, it is likely we were underpowered to detect differences based on year in program because of our use of a between-subject comparison. Future circus-specific studies should

aim to complete multi-year longitudinal trials to better assess the differences between student-artists based on years in program. Research from sport and dance in this area has reported mixed results[18,60,62–64]. A comprehensive study by Stanforth et al. of over 200 female NCAA division I athletes from a variety of sports exemplifies these equivocal findings[12]. In the study, the authors found that LM increased with time spent in program in volleyball players and swimmers, while percent FM increased in basketball players and no differences were detected in athletes from soccer and track and field[12].

Limitations

In the present study, we utilized multi-frequency bioelectrical impedance analysis to assess body composition. Comparisons to studies using other measurement devices and techniques should be performed with caution. Future studies should use a “gold standard” technique, such as dual-energy X-ray absorptiometry, to assess body composition changes in circus student-artists.

The results of this study relating body composition changes to year in program should be considered preliminary, as we performed between-group comparisons and were likely underpowered. Further longitudinal research is required to confirm these findings.

CONCLUSION

This longitudinal study reports positive adaptations in body composition over the scholastic year consistent with changes in RPE, and these adaptations occur for participants over a wide range of body compositions, and across disciplines and for both sexes. The study reveals that the program employed in this professional school results in positive physiological adaptations over semesters and over the scholastic year, reflecting program efficacy. This study emphasizes the importance of periodic assessments, as we also detected a likely maladaptation during the winter vacation, which

could have deleterious consequences for performance and could be a factor in elevated injury rates after extended time-off. Further research is indicated to examine the effects of vacation-based body composition shifts.

Beyond circus arts, the materials and methods utilized in this study can be replicated at a relatively low-cost and in a time-efficient manner which may be of interest to medicine and science professionals for application to other performing arts. As well, the results of this study illustrate important planning and intervention considerations within a yearly high-performance training season.

Future longitudinal research studies are required to examine the relationship of body composition to performance and injury, while controlling for objectively measured workload.

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Manuscript 3: Year-long variation of psychological characteristics of student-artists in an elite circus arts training program

In preparation for Work and Stress

Year-long variation of psychological characteristics of student-artists in an elite circus arts training program

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Abstract

Elite student-artists undertake extensive physical, technical, and artistic training for the high-risk demands of circus. Their training volumes exceed even those of high-performance athletes. Successful artist development requires a balance between stress and recovery. Previous research has shown that psychological and social stresses that result from everyday hassles (challenges) are contributors to overall stress. To our knowledge, this study is the first description of the magnitude and pattern of daily challenges in a circus population.

Ninety-two students at Ecole nationale de cirque (ENC) completed the Circus Daily Challenges Questionnaire (CDCQ) at four time points. State anxiety, perceived coping, fatigue, and measures of sleep data were also collected. The Kessler 6 Non-Specific Psychological Distress Scale (K6) was implemented at one time point for comparison.

The daily challenges and state anxiety of the student-artists covaried with fatigue ($p < 0.05$), while perceived coping scores remained consistent throughout the year. The highest levels of challenge and state anxiety occurred during the two exam periods, while the lowest scores were achieved following the extended breaks in the annual calendar. Daily challenge positively correlated to state anxiety and fatigue, and negatively correlated with perceived coping. The student-artists reported a substantially higher prevalence of moderate psychological distress to general populations. The development of interventions aimed at reducing the number and magnitude of daily challenges, while also enhancing the ability of student-artists to cope, is recommended and warrants future research.

Keywords: hassles, performers, anxiety, coping, mental

INTRODUCTION

Workers in high-risk environments, such as military and police personnel (Buehner et al., 2017; Deschamps, Paganon-Badinier, Marchand, & Merle, 2003), firefighters (Farioli et al., 2014), and extreme athletes (McIntosh, A., Fortington, L., Patton, D., & Finch, 2017), have the potential to be exposed to adverse workplace situations which can lead to serious injury or even death. Despite such serious risks to their own and their colleagues' well-being, workers in these environments commonly attribute their sources of work stress to more "minor", seemingly innocuous, stresses, known as daily hassles (Larsson, Berglund, & Ohlsson, 2016; Rodrigues, Kaiseler, Queirós, & Basto-Pereira, 2017). In one example, Biggam et al. studied nearly 700 Scottish police officers to examine the stressors associated with their work (Biggam, Power, Macdonald, Carcary, & Moodie, 1997). The authors found that, despite their risk of exposure to trauma, the most reported stressors were related to everyday organizational issues, such as staffing shortages and time pressures. (Biggam et al., 1997). This finding aligns well with the results from previous stress research that has long acknowledged that the accumulated influence of "minor" daily hassles may be even more impactful to a person's well-being than the stress resulting from major life events, such as a move to a new city or a divorce (Kanner, Coyne, Schaefer, & Lazarus, 1981; Tajallia, Sobhib, & Ganbaripanahab, 2010).

Daily hassles are defined as context-specific everyday factors that are common to most people, such as those arising from school, work, and interpersonal relationships (Rushall, 1990), and are perceived as stress-inducing (Delongis, Coyne, Dakof, Folkman, & Lazarus, 1982). A bi-directional relationship exists between hassles and symptoms, however protective factors, such as coping ability and support resources, have been shown to mitigate the negative consequences

that hassles and symptoms can have on one another (Larsson et al., 2016). Failure to effectively cope with daily hassles has been shown to have negative consequences for physical and psychological health and performance (Kanner et al., 1981; L. Lu, 1991; Tajallia et al., 2010).

Performing and training as a circus student-artist also entails serious risk. Student-artists perform acrobatic and aerial maneuvers at great heights and speeds, and technical errors or mechanical failures could lead to serious injury or even death (Donohue et al., 2018; Ross & Shapiro, 2017). To mitigate these risks, circus student-artists undertake intensive daily physical training and artistic and creative development (Filho, Aubertin, & Petiot, 2016). In fact, the total training hours of elite circus artists exceed those reported in high performance athletes (Decker, A., Aubertin, P., & Kriellaars, 2019). Academic life and its concomitant pressures offer additional daily stresses (F. J. H. Lu, Hsu, Chan, Cheen, & Kao, 2012).

Given the associations between daily hassles, physical and psychological well-being, and performance, and the demanding high-risk training environment in which circus student-artists must function, an exploration of the daily hassles of circus student-artists is of theoretical and practical interest.

Research outside of the circus population has developed tools to identify and quantify daily hassles within diverse environments (Ivarsson & Johnson, 2010; F. J. H. Lu et al., 2012). Adaptation of such tools, specific to the characteristics of a developing circus artist population, would permit evaluation of the daily hassles of circus student-artists while respecting the unique

demands, artistry, and culture of a circus training environment (Shrier & Hallé, 2011; Wanke, McCormack, Koch, Wanke, & Groneberg, 2012).

Knowledge of the specific daily hassles faced by student-artists, as well as their relation to other psychological and health determinants, such as state anxiety, perceived coping, non-specific psychological distress, sleep, and fatigue would be beneficial in both preventative and treatment-oriented approaches to overall well-being and performance through the creation of individualized interventions. Assessment over a full training year would allow for the elucidation of daily stress loading patterns with potential consequences to performance, injury and mental health.

The principle aim of this research was to characterize, for the first time, the daily hassles (which we refer to as *daily challenges*) of elite circus student-artists over one training year, examine the variation in daily challenges throughout the year, and to relate daily challenges to additional psychological and health measures including perceived coping, state anxiety, non-specific psychological distress, and fatigue. We hypothesized that:

1. Daily challenges, state anxiety, and perceived coping scores would vary throughout the training year in conjunction with overall fatigue
2. Individual daily challenge items (e.g., family relationships) would vary throughout the year
3. Daily challenge would correlate to state anxiety, perceived coping, and fatigue

4. Non-specific psychological distress scores would correlate to daily challenges, state anxiety, perceived coping, and fatigue. And, student-artists would report higher levels of non-specific psychological distress than general populations

We additionally aimed to assess if daily challenges, state anxiety, perceived coping, and non-specific psychological distress scores would correlate to measures of sleep. Sleep data were collected as part of a larger study.

METHODS

Participants

Data collection was undertaken at Ecole nationale de cirque (ENC) in Montreal, Quebec, Canada. Male (n = 60) and female (n = 32) circus student-artists (20.39 ± 2.42 years; height 170.01 ± 8.01 cm; mass 66.48 ± 11.07 kg) enrolled in the three-year professional program participated in the study. A detailed description of the program is provided by Decker et al (Decker, A., Aubertin, P., & Kriellaars, 2019). Ethical approval for the study was provided by the Human Research Ethics Board at the University of Manitoba. Informed written consent was obtained prior to participation.

Design

It has been recommended that the application of daily challenge measures occur at multiple time points given that daily stress is a state variable and fluid by nature (Fawkner, McMurrary, & Summers, 1999; Hanson, 1992; Ivarsson, Johnson, & Podlog, 2013). Therefore, a prospective

longitudinal, repeated measures design was used with collection at four time periods strategically placed throughout the school year: September (commencement of school following summer break); December (end of semester one, immediately prior to interim examinations for technical, physical, and artistic proficiency); January (return from winter break, commencement of semester two); and April (end of semester two, immediately prior to final examinations and performances).

Measures and Procedures

At each time point, the student-artists completed the Circus Daily Challenges Questionnaire (CDCQ). The CDCQ was adapted from the validated College Student-Athletes' Life Stress Scale (CSALSS) developed by Lu et al (F. J. H. Lu et al., 2012). To attain content validity and circus specificity, circus-specific daily challenges were added to the questionnaire following a consensus process which included consultation with circus-related psychologists, coaches, and performers, as well as members of the school's technical staff. A list of sixteen daily challenges were selected for inclusion: academic challenges, personal finances, family relationships, friend relationships, romantic relationships, staff relationships, schedule demands, language & culture, physical preparation, technical development, artistic expression, sleep, nutrition, overall coping, injury (fear of or return from), and substance abuse.

The student-artists rated the extent to which the sixteen specific daily stressors presented as a challenge in their lives. Each item was assessed using a six-point measurement system modelled from the CSALSS (F. J. H. Lu et al., 2012), from which two scores were derived for each item;

one for the level of the challenge and one for the ability to manage the challenge. The level score ranged from 0 (none) to 3 (high) and the management score ranged from 0 (no difficulty) to 2 (high difficulty). The inclusion of both a level and a management score was informed by Nilsson et al. who highlighted the importance of subjective appraisals of stressors (Nilsson, Hyllengren, & Ohlsson, 2015). While a circus student-artist may perceive the intensity of a specific challenge to be high, the effort required to manage the specific challenge may be low if the challenge is perceived to have little personal meaning or the individual has sufficient coping resources (Östberg, Plenty, Låftman, Modin, & Lindfors, 2018). An overall challenge level score was derived at each time point as the average across all sixteen items, as well as for the entire year. Similarly, an overall management score was derived for each time point and across the entire academic year.

In addition to the CDCQ, the student-artists concurrently reported their levels of state anxiety and perceived coping. Sleep and fatigue data were also collected at the same four time points as part of a larger study. State anxiety was assessed using a single-item scale (0 = no anxiety to 4 = high anxiety) modelled after the validated work of Davey et al. (Davey, Barratt, Butow, & Deeks, 2007). Perceived ability to cope was measured using a scale which assessed the student-artists' evaluation of their physical and mental capacity to manage stress (0 = lacks ability to 6 = very good ability) combined with an assessment of their perceived access to coping resources inside and outside of the school (0 = no resources to 3 = very good resources). The four scores were summed to derive a total perceived coping score (0 - 18).

Sleep and fatigue were assessed via a seven-day sleep log modified from the validated Consensus Sleep Diary (Carney et al., 2012). Sleep duration (hours) was derived from the recorded times for falling asleep and waking. Sleep latency (difficulty falling asleep, 1 = easy to 10 = difficult), sleep quality (overall quality of sleep, 1 = excellent to 10 = poor), wakefulness (how refreshed upon waking, 1 = refreshed to 10 = not refreshed), and fatigue (overall mental and physical fatigue level, 1 = little to 10 = exhausted) were assessed using ten-point numerical rating scales.

We utilized the six item, Kessler Non-Specific Psychological Distress Scale (K6) to screen for moderate to severe non-specific psychological distress (Kessler et al., 2002) during the December time point. K6 scores between 8 and 12 were designated to indicate moderate psychological distress, while severe psychological distress was designated by scores equal to or greater than 13 (Fushimi et al., 2012). As the K6 also probes feelings about the previous thirty days, it was used to derive; the frequency of negative feelings/emotions, the number of training hours lost due to negative feelings/emotions, how often physical health problems were the cause of negative feelings/emotions, and the total number of doctor visits.

Statistical Analyses

Basic descriptive statistics were derived for each parameter. Friedman test with Durbin-Conover pairwise comparison was used to examine the effect of time (within-subject), sex (between-subject), and year-in-program (between-subject). Spearman correlation was used to assess the relationships between challenges, state anxiety, perceived coping, psychological distress, fatigue,

and sleep measures. We also used K6 to classify the student-artists into low, medium and high psychological distress categories to examine gradients in challenges, state anxiety and perceived coping measures. SPSS (v23.0) statistical software was used for analysis. Alpha was set at a level of 0.05.

RESULTS

Table 1 summarizes the overall daily challenges (level and management), state anxiety, perceived coping, and fatigue scores of the student-artists at each of the four time points. The overall challenge level, challenge management, and state anxiety scores covaried with fatigue through the school year, while the perceived coping scores remained stable. No statistically significant differences were found between sexes or year in program for any of the variables.

Table 1. Overall daily challenge, state anxiety, perceived coping, and fatigue scores at each time point (mean, SD)

	September	**December**	**January**	**April**
Challenge Level (0 to 3, low to high)	1.11# (0.45)	1.20+ (0.44)	1.01^ (0.44)	1.13 (0.44)
Challenge Management (0 to 2, low difficulty to high)	0.12* (0.16)	0.17+ (0.18)	0.09^ (0.12)	0.11 (0.12)
State Anxiety Level (0 to 4, low to high)	1.71* (0.93)	1.93+ (0.87)	1.59^ (0.89)	1.81 (0.95)
Total Perceived Coping (0 to 18, low to high)	12.49 (2.81)	12.46 (3.19)	12.59 (2.89)	12.30 (2.88)
Fatigue (1 to 10, low to exhausted)	4.78* (2.16)	5.87+ (1.86)	4.68^ (2.31)	4.81 (2.16)

** statistically significant variation between September and December ($p < 0.05$), Friedman*
+ statistically significant variation between December and January ($p < 0.05$), Friedman
^ statistically significant variation between January and April ($p<0.05$), Friedman
 # trending to significance ($p<0.08$)

Figure 1 demonstrates the yearly variation in specific daily challenge levels. The student-artists identified schedule demands as the highest aggregate challenge item, followed by technical development, artistic expression, physical preparation, and sleep, respectively. The student-artists' relationships with staff (including their coaches) was rated as the lowest level of challenge, followed by substance use and family relationships. Only two of the sixteen challenge items revealed no systematic variation through the year; nutrition and substance use. A sex-based difference in challenge level was observed only for substance use ($p < 0.001$), with males reporting higher scores than females ($p < .001$).

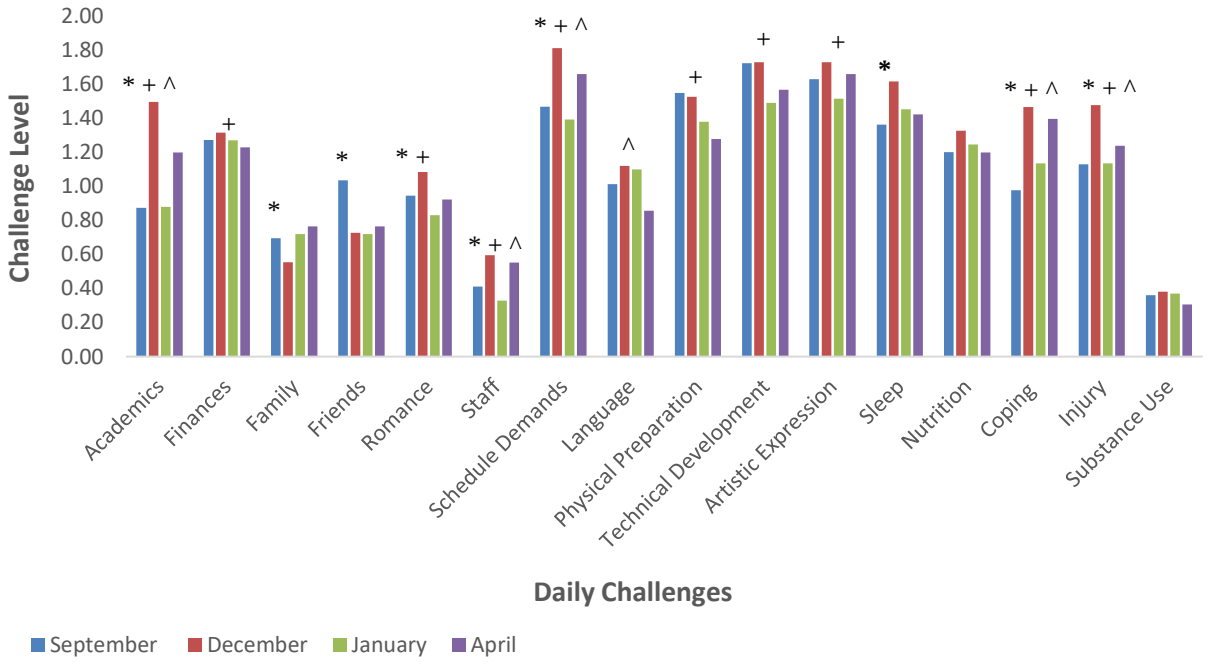

Figure 1. Daily challenge level scores at each time point
** statistically significant variation between September and December ($p < 0.05$)*
\+ statistically significant variation between December and January ($p < 0.05$)
^ statistically significant variation between January and April ($p<0.05$)

Figure 2 reports the percentage of student-artists at each time point reporting management issues with each specific challenge item. Sleep, artistic expression, and fear of injury were the challenges reported most frequently by the student-artists as difficult to manage over the course of the academic year. The number of challenges reported as difficult to manage varied throughout the year, with the highest number of challenges reported in December (196) and the lowest in January (112). Notably, 63%, 75%, 66%, and 70% of student-artists reported having difficulty managing at least 1 daily challenge in September, December, January, and April, respectively. On average for the year, 25% and 15% of student-artists reported undesirable (midpoint of the scale) state anxiety and perceived coping scores.

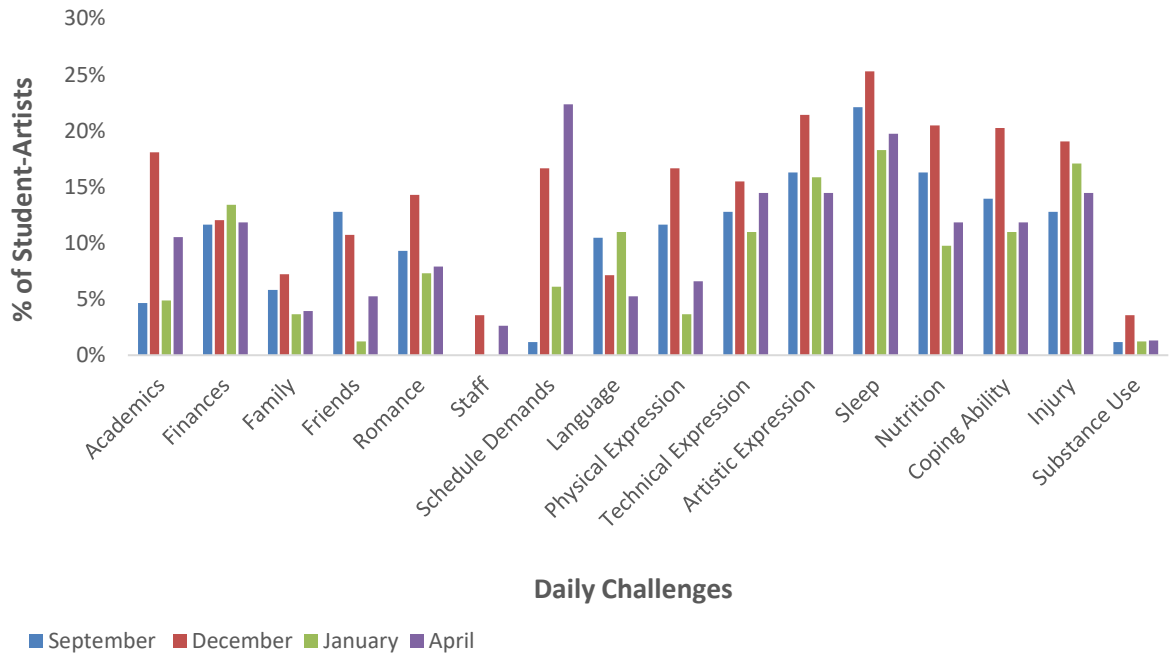

Figure 2. Percentage of student-artists at each time point reporting difficulty managing each daily challenge item

Figure 3 reports the percentage of total scores over the year classified as “difficult to manage” and “highly challenging, but manageable” for each daily challenge item, demonstrating the importance of including both a level and a management score to assess daily challenges.

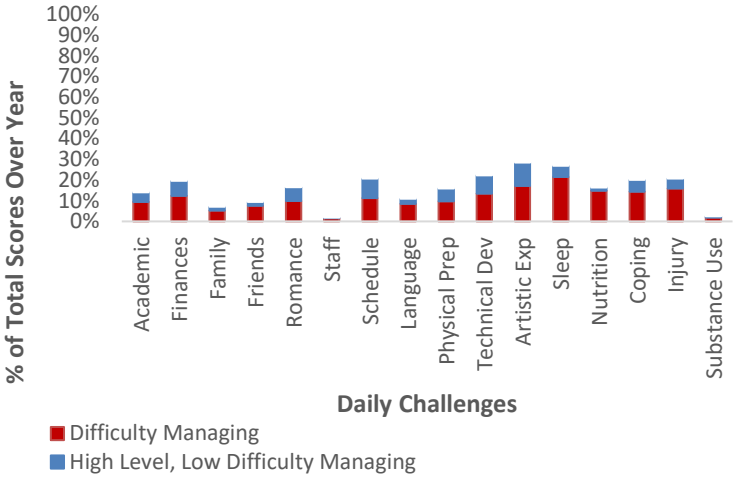

Figure 3. Percentage of total yearly scores classified as “difficult to manage” and “highly challenging, but manageable” for each daily challenge item

Tables 2 and 3 show the correlations between key variables. Table 2 summarizes the correlations between fatigue, daily challenges, state anxiety, and perceived coping at each time point and over the year. Table 3 reports the relationships between daily challenges, state anxiety, perceived coping, sleep characteristics, and K6 scores during December, the time period during which the K6 data was collected. The relationships between daily challenges, state anxiety, perceived coping, and sleep characteristics showed consistency at all time periods.

Table 2. Spearman correlations at each time point and over the year for daily challenges, state anxiety, total perceived coping, and fatigue

		Fatigue	Challenge Level	Challenge Management	State Anxiety	
September	**Fatigue**					
	Challenge Level	0.35*				
	Challenge Management	0.39*	0.63*			
	State Anxiety	0.10	0.44*	0.36*		0.80
	Perceived Coping	-0.12	-0.20*	-0.19	-0.39*	0.70
December	**Fatigue**					0.63
	Challenge Level	0.42*				0.50
	Challenge Management	0.31*	0.74*			0.40
	State Anxiety	0.08	0.52*	0.50*		0.30
	Perceived Coping	-0.20*	-0.45*	-0.43*	-0.38*	0.20
January	**Fatigue**					0.10
	Challenge Level	0.38*				<0.10
	Challenge Management	0.33*	0.73*			
	State Anxiety	0.26*	0.55*	0.47*		-0.80
	Perceived Coping	-0.42*	-0.48*	-0.41*	-0.31*	-0.7
April	**Fatigue**					-0.60
	Challenge Level	0.53*				-0.50
	Challenge Management	0.53*	0.69*			-0.40
	State Anxiety	0.47*	0.54*	0.46*		-0.30
	Perceived Coping	-0.29*	-0.57*	-0.47*	-0.48*	-0.20
Year Average	**Fatigue**					-0.10
	Challenge Level	0.50*				<0.10
	Challenge Management	0.33*	0.83*			
	State Anxiety	0.40*	0.71*	0.39*		
	Perceived Coping	-0.48*	-0.60*	-0.38*	-0.42*	

** statistically significant $p < .05$*

Table 3. Spearman correlations for daily challenges, state anxiety, perceived coping, sleep measures, and K6 during the December time period

	Fatigue	Sleep Duration	Wakefulness	Sleep Quality	Sleep Latency
Challenge Level	0.42*	-0.14	0.39*	0.24*	0.17
Challenge Management	0.31*	-0.21*	0.35*	0.13	0.10
State Anxiety	0.08	-0.05	0.18	0.11	0.25*
Perceived Coping	-0.20*	0.20*	-0.06	-0.09	-0.35*
K6	0.35*	-0.05	0.39*	0.30*	0.12

** statistically significant p < .05*
Reminder: High sleep duration and perceived coping scores are desirable. High K6, wakefulness, sleep latency, sleep quality, challenge level, challenge management, and state anxiety scores are undesirable

Table 4 shows the stratification of student-artists based on their K6 score; severe K6 (> 12), moderate K6 (8 to 12), or low K6 (< 8). Student-artists in the severe K6 group had significantly higher daily challenge level, daily challenge management, state anxiety, and fatigue scores, and significantly lower perceived coping scores than those in the low K6 group ($p < 0.05$). Student-artists in the severe K6 group also reported a higher number of training hours lost due to negative feelings/emotions ($p = .022$) and trended toward a higher number of visits to their doctor ($p = .067$) in the previous 30 days. Based on their K6 scores, 9%, 42%, and 49% of the student-artists were classified as severe, moderate, and low psychological distress, respectively.

Also shown in Table 4 are the challenge items for the seven student-artists in the severe K6 group. Among these student-artists, there was diversity in the factors related to their severe psychological distress. Further, there was variety in the challenge items reported among the individuals; substance use, injury, family, schedule demands (x2), romance, and sleep.

Table 4. Stratification of measures using non-specific psychological distress (K6)

	Challenge Level	Challenge Management	State Anxiety	Perceived Coping	Fatigue
Severe K6	1.51* (0.36)	0.32* (0.19)	2.68* (0.48)	10.23* (3.33)	6.39* (1.58)
Moderate K6	1.24++ (0.34)	0.15+ (0.11)	2.03++ (0.61)	11.84++ (2.48)	5.20+ (1.79)
Low K6	0.94^^ (0.34)	0.09^ (0.09)	1.42^^ (0.66)	13.31^ (1.80)	4.48^ (1.53)
Severe K6 - 1	1.90	0.53	3.00	11.00	6.33
Severe K6 - 2	1.39	0.43	3.00	14.00	8.00
Severe K6 - 3	1.78	0.55	3.00	4.33	8.00
Severe K6 - 4	1.66	0.30	3.00	7.50	5.00
Severe K6 - 5	1.71	0.24	2.33	12.33	6.75
Severe K6 - 6	0.89	0.08	2.67	10.00	7.00
Severe K6 - 7	1.24	0.13	1.75	12.50	3.67

** or ** statistically significant difference between severe K6 and moderate K6 ($p < 0.05$ or $p < 0.001$)*
+ or ++ statistically significant difference between moderate K6 and low K6 ($p < 0.05$ or $p < 0.001$)
^ or ^^ statistically significant difference between low K6 and severe K6 ($p < 0.05$ or $p < 0.001$)

DISCUSSION

The present study characterised the daily challenges faced by circus student-artists over the course of one training year, in relation to their levels of state anxiety, perceived coping, non-specific psychological distress, sleep, and fatigue. The results reveal several important considerations.

In agreement with our first hypothesis, we observed significant variation in daily challenge and state anxiety scores through the training year consistent with the demands of the program, indicated by the student-artists' fatigue scores. Student-artists' daily challenge, anxiety, and fatigue scores peaked immediately prior to the two examination periods in the training calendar

(December and April). This finding brings to light a possible intervention strategy. School administrators and coaches should plan to taper (reduce training volume) the student-artists' workload for one to two weeks leading into each of the two academic and performance exam periods. Effective short-term tapering strategies have shown to enhance physical performance by up to 3% (Le Meur, Hausswirth, & Mujika, 2012). A reduction in physical training load would also create more time for mental preparation and stress-reducing interventions, which could minimize daily challenges and further maximize preparation and recovery (Le Meur et al., 2012).

The lowest daily challenge, state anxiety, and fatigue levels were recorded following periods of extended time-off. This finding offers support to the notion that planned extended breaks in annual performance plans provide necessary opportunities for mental and psychological recovery (Meeusen et al., 2013; Solomon & Weiss Kelly, 2016). It is important to note, however, that the average fatigue level of the student-artists was still near the mid-point of the scale. Individualized recovery strategies provided to each student-artist during the summer and winter vacation periods would help to ensure near-total rejuvenation prior to returning to school and the resumption of full training.

The covariation of daily challenge, state anxiety, and fatigue aligns with resource depletion theory (Hobfo, 1989; McEwen, 1998), which indicates that individuals will struggle to self-regulate and manage tasks when resources run thin (Baumeister, 2003). One iteration of this theory at work is that as the number and/or the intensity of daily challenges increases to a point that is no longer tolerable, other challenges in life (training workload) seem harder to manage than at times when stress is low. The negative impacts of such a bidirectional "snowball" effect

could then spill over into additional psychological domains (e.g. state anxiety) and, ultimately, into performance. This notion is further supported by our finding that daily challenge, state anxiety, perceived coping, and fatigue all align within the K6 gradient (Table 4). Targeted interventions aimed at the reduction or removal of specific daily challenges while also enhancing access to coping resources should be implemented. Such an interventional strategy would be in agreement with the social ecological model of resilience (Ungar, Ghazinour, & Richter, 2013) and the stress process model (Mcleod, 2012), both of which indicate that improving resources in one psychological domain may provide protective mediatory effects against adversity in another (Ungar, 2011).

Contrary to our first hypothesis, the perceived coping scores of the student-artists did not vary throughout the training year. We also found no difference in perceived coping scores between first- and third-year student-artists. Taken together, these findings indicate that experience in the high-performance circus training environment, alone, was not a means for improvement in coping, whether that experience was contextualized within one training year or across several years. This indicates a possible intervention strategy. Given the relationship between coping self-efficacy scores and performance in sport (Nicholls, Polman, & Levy, 2010; Reeves, Nicholls, & McKenna, 2011), the implementation of interventions designed to increase circus student-artists' access to coping resources and to enhance their intrinsic coping skills could prove beneficial for improvements in performance in circus, as well. The statistically significant gradient in coping scores with respect to K6 appears to support such interventions, given that those individuals with the poorest coping scores also reported severe psychological distress. This finding opens several novel avenues of research to elucidate effective interventional approaches.

In agreement with our second hypothesis, we observed statistically significant variation in individual daily challenge items between time points. In fact, only two of the sixteen daily challenge items failed to show significant variation between at least one set of time points. We found that over 90% of student-artists reported difficulty managing at least one daily challenge throughout the year, 36 to 52% reported difficulty managing multiple challenges at each measurement period, and one in four student-artists averaged undesirable state anxiety scores over the year. The variation in daily challenge items throughout the year offers further support to the notion that daily challenges should be monitored at multiple time points (Fawkner et al., 1999).

As we anticipated in our third hypothesis, daily challenge scores significantly correlated to state anxiety (positive), perceived coping (negative), and fatigue (positive). Further, the relationships between variables showed consistency over time, despite variation in the scores of individual challenges across time periods.

And, in agreement with our fourth hypothesis, we found that the student-artists' K6 scores positively correlated to daily challenge, state anxiety, and fatigue, and that the student-artists reported substantially higher prevalence rates of moderate psychological distress than reported in general populations (Enticott et al., 2018; Fushimi et al., 2012; Slade, Grove, & Burgess, 2011). For comparison, Prochaska et al. reported that 27.9% of Californian adults measured in the moderate K6 category (Enticott et al., 2018), whereas in our study, over 40% of the student-artists were stratified as moderate psychological distress. Despite these findings, we did not find a greater prevalence of severe psychological distress in this developing circus artist population

(Enticott et al., 2018; Fushimi et al., 2012; Slade et al., 2011). And, for further comparison, a recent study by Sullivan et al. of Canadian student-athletes reported that nearly 20% of the student-athletes exceeded the threshold for severe mental distress (Sullivan, Blacker, Murphy, & Cairney, 2019), whereas less than 10% of the student-artists in our study were classified in the severe category. It is possible, then, that undiscovered protective factors may exist in the selection (recruitment) of individuals for the training program. To the authors' knowledge, this is the first study to publish the prevalence rates of non-specific psychological distress in a circus population and prompts further research into this area which may be beneficial not only to circus student-artists, but also to professional circus artists and other high-performance environments (dance, military, sport).

Finally, as an additional aim of this study we aimed to determine if daily challenges, state anxiety, perceived coping, and non-specific psychological distress scores would correlate to measures of sleep. In alignment with previous reports, we found statistically significant relationships between sleep characteristics and daily challenges (Weller, L., Avinir, 1993), state anxiety (Pires, Bezerra, Tufik, & Andersen, 2016), and non-specific psychological distress (Cunningham, Wheaton, & Giles, 2015), and coping (Sadeh, Keinan, & Daon, 2004).

Strengths and Limitations

A strength of this study was our use of a multi-item daily challenge measure in a repeated-measures design as it allowed us to identify periods of high daily challenge and the specific daily challenges producing stress at each specific time point. Had we used only the non-specific psychological distress scale, we would not have been provided insights into the individually-

specific factors that influenced the psychological well-being of the student-artists. Workplace research has previously demonstrated the value of identifying specific causes of daily stress prior to designing stress-reduction interventions (Ahmad et al., 2015; Bhui, Dinos, Galant-Miecznikowska, de Jongh, & Stansfeld, 2016; Michie, 2002). Additionally, a recent (2018) study by Clement and coworkers of amateur and elite soccer players found that variations (increases) in self-reported daily stress symptoms within a season were associated with an increased risk for injury (Clement, Ivarsson, Tranaeus, Johnson, & Stenling, 2018), thus highlighting the importance of multiple, appropriately-spaced time points to capture training season variations. Understanding these patterns is an essential step necessary for the creation of interventional approaches to mitigate safety issues and maximize performance gains.

A limitation of this study was that we did not report on the quality of technical or artistic performances during this time period and, therefore, could not interpret the effect of psychological variables on these parameters. We recommended that future research directly explore the relationships between daily challenges and non-specific psychological distress to performance.

Conclusions

The implementation of both a specific daily challenge scale, such as the CDCQ, and a non-specific psychological distress scale, such as the Kessler K6, at multiple time points allows for the identification of individuals experiencing severe psychological distress, periods of high daily stress, and the specific causes of high daily stress with respect to each time point.

The development of individualized interventions designed to reduce daily challenges and state anxiety, improve coping, and to maximize physical and psychological recovery is recommended. Such an interventional approach fits within the stress process model and social ecological model of resilience. More research is needed in this area to optimize interventional approaches.

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CONFLICT OF INTEREST

This study was funded through the SSHRC Industrial Research Chair in Circus Arts. No potential conflict of interest was reported by the authors.

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Manuscript 4: Putative mechanisms of elevated injury rates after vacation break in elite circus artist students

Putative mechanisms of elevated injury rates after vacation break in elite circus artist students

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Introduction

The type, location, mechanisms and rates of injuries of professional performers and student-artists in circus have been documented (Goudard, Perrin, & Boura, 1992; Hamilton et al, 2011a; Hamilton et al, 2011b; Hamilton et al, 2012; Long, Ambegaonkar & Fahringer, 2011; Munro, 2014; Orlando et al, 2011; Shrier et al, 2014; Shrier et al 2009; Shrier & Hallé, 2011; Stubbe, Richardson & Van Rijn,2018; Wanke et al, 2012; Wolfenden & Angioi, 2017). Overall, circus injury rates are relatively modest in comparison to similar sports (Cossin, 2019); a rate of 9.7 injuries/1000 artist exposures in professional circus artists compared to 15.2 injuries/1000 exposures in collegiate women's gymnastics (Shrier et al, 2009). However, the variation in injury rates within the training year for circus artist students and within the performance year for professional artists has not been well elucidated. Specifically, although there are many anecdotal reports of increased injuries after vacation or after periods of shows going "dark" in the circus settings, there is very little data supporting this contention.

Orlando and coworkers (2011) examined the influence of weekly days off in professional touring circus artists based upon the hypothesis that days off would mitigate injury risk through reducing cumulative fatigue and subsequently limit over-use and overtraining-related injuries, a popular sport-based notion that is largely based upon endurance athletes (Cosca & Navazio, 2007; Hreljac, 2004; Korkia, Tunstall-Pedoe & Maffulli, 1994; Popovich et al, 2000; van Mechelen, Hlobil & Kemper, 1992). This study, paradoxically to the authors, demonstrated elevated injury rates requiring medical attention after extended days off, but confirmed suspicions of those in the circus industry. The authors proposed an explanation for the elevated injury rates related to the negative impact of a break on the "timing of precision acts" (Orlando et al, 2011), likely

referring to deficits in motor control on the individual or group level arising after prolonged breaks. This study was designed to examine relative rest and not the impact of vacation, per se, on injury rates, and was appropriately delimited to the professional circus setting. Examining the injury rates after vacation in elite circus student artists would provide additional insights into this phenomenon.

Interestingly, studying the same professional circus company as Orlando and colleagues, Bolling and coworkers (2019) published a work using focus groups for the purpose of injury concept mapping. This mapping exercise identified multiple injury factors that could be categorized as intrinsic and extrinsic to the circus artists, as well as related to prevention strategies and stakeholders. It also identified the importance of multi-level prevention approaches unified across stakeholders. The injury mechanisms proposed by Bolling and colleagues (2019) were in the general context of circus and not specific to prolonged breaks. Exploration of mechanisms specific to the context of return from prolonged break would provide added insight into circus specific injury factors.

Understanding the impact of a prolonged break, a vacation, or changing from one contract to another is important in the circus industry and the artists' welfare. Further, it is important to examine and identify all potential factors that could be implicated in causing higher rates of injuries after prolonged break so that effective prevention strategies can be implemented and further researched.

This chapter provides a multi-year analysis of the injury rates after winter vacation of high-performance circus student-artists. Further, it documents the changes in physical and psychological factors over the course of the break to examine potential contributory factors. Finally, this chapter articulates and discusses the putative mechanisms underlying the elevated injury rates specific to the context of prolonged breaks or vacation.

Methods

The injury data base from the National Circus School in Montreal, Canada, was used to explore the injury rates over eight years of elite student-artists enrolled in a three year, college professional program. Over the eight years, there was a range in enrolment of 75 to 105 students per year. All injuries requiring treatment were included in the analysis, as well as concurrent injuries in the same participant. We report injury hazard as the mean injury rate over a fixed unit of time (Hopkins et al, 2007). The analysis of injury rates was performed over the entire scholastic year, but this study reports on the period surrounding the winter vacation months (December, January and February). A winter break nominally lasting three weeks is provided after the first week in December to the first week of January.

Meetings with staff at the school including administrators, coaches, exercise physiologists, performance psychologists, physicians, athletic therapists were convened to discuss the potential factors implicated in this elevated injury rate. Focus groups meeting with students were performed to understand their understanding of “taking a break”, as well as any insights they may have into post break injury mechanisms.

In the last of the eight years, measurements of sleep (duration, latency, quality), fatigue, body composition (Inbody 230), daily hassles/challenges, state anxiety, and perceived coping were tracked just prior to and immediately after winter vacation. Changes in these parameters are reported descriptively to provide context for understanding the putative mechanisms underlying elevated injury rates after break. Informed consent was provided by the participants and the study was approved by the research ethics board of the University of Manitoba.

Results

Injury Rates

Visual inspection of the injury rate patterns revealed ostensibly identical patterns across all eight years. Figure 1 shows the weekly injury hazard rates for December to February averaged over eight years. Elevated injury rates are evident for the post-vacation period in January (mean 5.6 per week, peak 6.1), with an elevated period of approximately three weeks. Averaged weekly injury hazard rates for the entire “in school” period was 3.7 injuries per week, with 3.11 in December, and 2.9 in February.

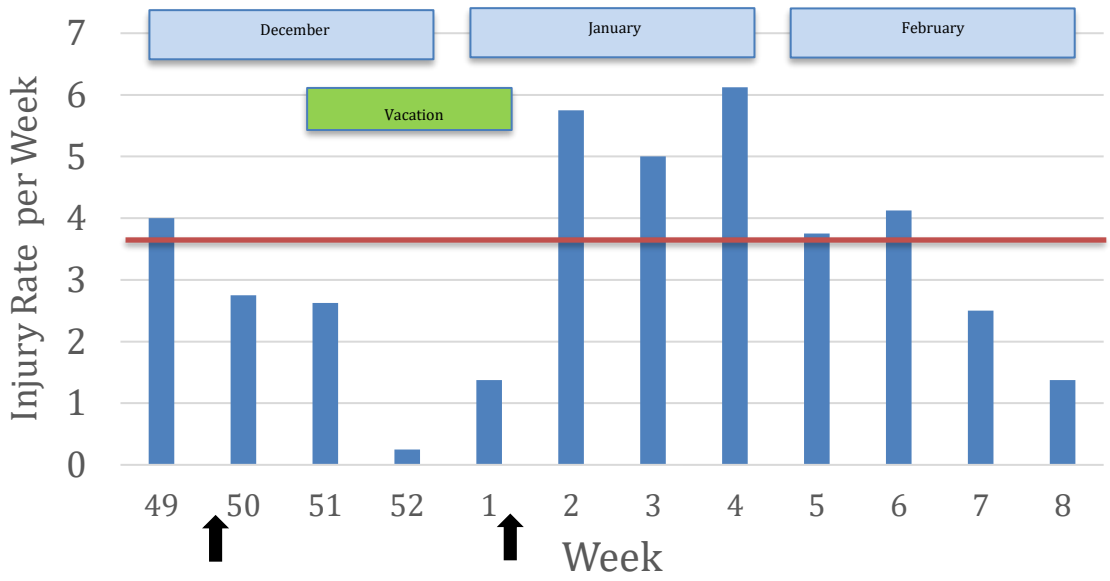

Figure 1. The weekly injury rates of (averaged over 8 years) for the months of December, January and February. The nominal vacation period is illustrated. The "in school" average weekly injury rate is shown (red line). Pre- and post-vacation measurements periods indicated by arrows.

Physical and Psychological Changes Over Winter Break

Over the three-week break period, there was an average increase in body fat of 1.3% and a decrease in skeletal muscle mass of 0.7%. There were 2% of students identified with dehydration upon return from vacation. The average sleep duration was 8 hours 24 minutes in December and 8 hours 36 minutes upon return from break (not significant). Nearly 20% of students reported short sleep durations and about 10% reported difficulty sleeping (latency, quality). Perceived coping (internal and external capacity and resources) remained constant across the break period. Total daily challenge and state anxiety reduced statistically over the break. The total number of challenges requiring management by the students was the lowest of the year upon return from break. Students reported the lowest levels of fatigue for the year upon return from break, however 31.7% still reported elevated and undesirable fatigue levels.

Putative Mechanisms

Below is a list of factors categorized from the meetings with staff and students using the injury concept mapping framework of Bolling and coworkers (2019). Beside each putative factor is an estimated period of impact on injury risk. Given that the elevated injuries occur for the last three weeks of January and abate in February, there may be distinct factors implicated for each of the weeks after return from break and these factors are likely highly individual.

Artist-Related or Intrinsic Factors

- Travel Fatigue (Day 1-4)

  Travel fatigue is known to negatively influence focus and attention, and can have potential consequences on general fatigue state, and therefore neuromuscular activation patterns of the individual. Some students have travel durations exceeding 30 hours during their return to school from vacation. Some will have long travel durations from the southern hemisphere to the northern hemisphere without involving jet lag.

- Jet Lag (Day 1-6)

  The consequences of jet lag on diurnal rhythm are known to negatively affect the body in multiple ways including focus and concentration, and general state of readiness to perform tasks (Reilly, Waterhouse, & Edwards, 2005). Many students have time zone shifts of 2 to 14 hours after return from vacation.

- Hydration (Day 1-2)

  Dehydration upon return to school is possible due to changes in nutrition patterns and, secondarily, due to travel. Dehydration is a well-documented cause for inhibited performance (Robson-Ansley, Gleeson, & Ansley, 2009). Measurements indicate that less than 2% of students experienced dehydration.

- Physical Slippage or Detraining (Day 1-20)

  Another well-documented performance factor is body composition (Minett, Binkley, Weidauer, & Specker, 2017). An average increase in body fat of 1.3% represents an increase in body mass that could influence body trajectories during motion, as well as influence the load carrying of the individual that support them. This coupled with a loss of muscle (0.7%) and any neural activation limitation due to relative rest, could result in a decreased ability to generate adequate torque for specific skill executions including adapting to mis-executions.

- Negative caloric balance (Day 3-20)

  Some students undertake self-directed programs to lose the adipose tissue gained during break. This requires a negative caloric balance, likely attained through food restriction. A negative caloric state can have undesirable impacts on mood, fatigue, focus, decision making and concentration due to low blood glucose levels. This could also impact self-efficacy, which is also known to influence injury rates.

- Technical Slippage (Day 1-14)

  While on break, the ability to maintain technical skills in certain disciplines would be impossible without suitable equipment and facilities (for instance swinging trapeze). Certainly, a reduction in the frequency and duration of training would likely detrimentally impact the movement competence of the student. This could be a key factor in the elevated rates of injury as suspected by Orlando and colleagues (2011).

- Persistence of the effects of substance use (Day 1-1.5)

  Since the return to school is timed with New Year celebrations with friends and family, it is possible that use or misuse of recreational substances, like alcohol and marijuana, could impact performance upon return. Performance decrements have been shown to last up to 24 hours after use for marijuana (Leirer, Yesavage & Morrow, 1991).

- Fatigue (Day 1-30)

  Not all students return with low levels of general fatigue due to a variety of reasons. The inability to recover from high levels of fatigue at the start of the term is implicated in higher risk of injury.

- Sleep (Day 1-30)

  For some students (10-20%), sleep characteristics were not optimal, but may have been altered by travel or other factors unique to this time-period. Sleep quantity and quality has been shown to be related to accuracy, reaction time and longer duration power output (Decker, Aubertin & Kriellaars, 2019). The students identify sleep as one of the most difficult challenges of the program.

- Participant expectations for training (1-14)

  The students may return with unrealistic expectations for return to pre-vacation performance, and engage in over-training or, conversely, in a laissez-faire attitude.

- Relationship Rifts (Day 1-10)

  For some students, winter break can be difficult on family, friend and romantic relationships as identified in the life challenges surveys. Returning from break with a rift in any relationship can be a factor in creating increase stress levels and impact on injury risk (Hanson, 1992).

External Factors

- Resocialization (Day 1-5)

  During the first few days upon return from vacation students are engaged in resocialization with fellow students and staff. This could have potential impact on focus during training by creating distraction for both staff and students.

- Coaching and technical staff factors (Day 1-30)

  Coaches and technical staff may have returned with inadequate rejuvenation and may have to reacquire their attentive nature after vacation. Also, coaches may not have the same expectations as the students for return-to-performance during the weeks following vacation. Although coaches were aware of the idea of a “reverse taper”, the actual implementation of this was not clear.

- Shift to artistic requirements from technical and physical (Day 1-30)

  The students identify a shift in focus from physical preparation and technical ability to artistry and creation from first to second term. An artistic counsellor partakes to a greater extent in student training after winter break. This creates a triad of actors (student, coach and counsellor) that may have unintended consequences for negotiation of activities of the student.

- Seasonal affective impacts (Day 1-30)

  The students return to a regimented program with little ability to escape darkness. In January in Montreal, they will enter and leave the school in dark and have very little exposure to light. Although, the true seasonal affective disorder may exist, the more subtle impact of a short diurnal duration of performance may play a role in injury.

- Nutrition Shift (Day 1-7)

  The eating behaviours of the students would need to realign with the rigorous schedule demands of the program. This could unintentionally result in inadequate caloric input and timing of input.

Preventative Strategies

- General or individual specific training programs for maintenance (Day 1-30)

  There are no general or specific training programs prescribed for the students to undertake during break. There are no educational sessions provided to the students or staff regarding what constituent minimal levels of training for physical maintenance or to prevent technical slippage in motor skills.

- Understanding of rejuvenation or regeneration approaches (Day 1-30)

  There are no strategies provided to students or staff for psychosocial well-being during the break so as to return with minimal stress and fatigue.

- Rapid stress accumulation (Day 1-7)

  Although the students, on average, return with the lowest levels of fatigue and stress for the year, the full program schedule is applied and the students experience a rapid onset of stress in the first week upon return.

- Mutual adaptation of expectations (Day 2-30)

  The staff and students are not providing training or resources in negotiation of expectations for training in the first weeks following return from break. Mismatches in training and performance expectations could be implicated in injury risk.

- Workload and Schedule (Day 1-30)

  The schedule upon return resumes at “full pace” without an adaption of schedule for graduated return to participation. At face value, although the schedule may be full, there is room for negotiation of workload within each class based upon mutual adaptation of expectations between teachers and students.

- Treatment Interruption (Day 1-30)

  For those with an injury prior to break, the treatment options would change during break and may result in an interruption or gap in the return-to-train protocol.

Conclusion

This study provides the first evidence of elevated injury rates after return from winter break in elite circus student-artists, consistent with observations made in professional troupes (Orlando et al 2011). Any one of the factors or in combination could be implicated in the elevated injury rates observed after return from winter break. Each of the factors has an operational time window and given the broad window of elevated injury rates it is likely that the causes are multi-factorial. The list of factors contextually provided in this study overlap and extend the factor list reported by Bolling and group (2019). Further, our measurements clearly show that there are distinct sub-sets of students that carry individually-specific risk factors for increased injury and that a single over-arching factor does not seem to be at play. The comprehensive monitoring system we employed could be used to "trap" individuals that meet specific criteria for high risk of injury and aid in tailoring interventions to the individual. The list of putative mechanisms provides a starting point for exploration of strategies to mitigate against increases in injury upon return from extended breaks, as well as provides a foundation for future research into the actual factors implicated. Further, by retrospective analysis of the database we could associate these characteristics with injuries that have occurred post-break, or preferably prospectively intercede to observe a reduction in injuries in the January time period. Circus artists are under substantial pressures to perform exceptionally without reprieve, have a fear of losing everything, and have

the necessity to adapt to ever changing settings in shows and training (Cayrol et al 2019). It is imperative that we provide the optimal milieu for the artist to continue to perform.

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General Discussion

The present thesis aimed to characterize physical, physiological, and psychological factors related to the performance and health of elite circus student-artists using strategic measurements in a longitudinal study over one scholastic year.

Manuscript 1 tracked key sleep parameters (duration, quality and latency) of circus student-artists at four time points over the training year. Results revealed that student-artists, on average, reported longer sleep durations than those self-reported in elite athletes. Manuscript 1 also demonstrated that the sleep parameters of the student-artists remained stable throughout the year, while their fatigue scores covaried with changes in RPE. Despite an average sleep hygiene exceeding that of their athlete counterparts, this study also identified that there were about 20% of the student-artists with specific sleep deficits in terms of latency, quality or duration. This information was invaluable for developing tailored educational interventions for the student body.

Manuscript 2 characterized the body compositions of circus student-artists and assessed body composition responses to changes in training load over the year. The results revealed that muscle mass covaried with RPE, while fat mass decreased with increases in RPE, resulting in a gain in muscle mass and loss in fat mass during each of the two semesters and over the training year. These findings verified that the scholastic programming was effective in developing physical characteristics of circus performers over the training year and through successive years in the program. In addition, a three-week vacation resulted in

increased fat mass and reduced muscle mass, reflecting a period of detraining. The vacation period-induced body composition alteration was important to document as it may be a factor in elevated injury rates upon return from vacation.

Manuscript 3 characterized student-artists' daily challenges over the entire training year and related them to additional psychological factors; state anxiety, perceived coping, and non-specific psychological distress. Results revealed that the magnitude of circus student-artists' daily challenges and state anxiety levels covaried with their overall fatigue levels, while the perceived coping scores remained consistent throughout the year. There were highly individualized responses across the student-artists, reflecting that a generalized approach may be unsuitable. Individualized interventions focusing on the removal or mitigation of specific stressors, combined with improvements in internal coping ability and better access to coping resources are recommended. Such an interventional approach aligns with the stress process model and the social ecological model of resilience. Manuscript 3 also revealed that circus student-artists reported a substantially higher prevalence of moderate psychological distress than general populations. Despite the arduous demands of the program, the rate for severe distress was equivalent to those found in general population studies and lower than reported in a study of collegiate athletes.

Manuscript 4 examined the injury rates of the student-artists during the time period surrounding their three-week vacation period separating the first and second semesters. Results showed an elevated rate of injury following return from vacation relative to the

training year and semesters. Manuscript 4 also provided a comprehensive list of putative mechanisms for the increased injury rate following the vacation period. The identification of putative factors was important so that a response bias to early findings (such as the adverse body composition changes due to the vacation period) would be controlled.

Knowledge Translation Outcomes

The projects outlined in this thesis were conducted within a translational research framework related to training optimization in circus arts using an actionable dashboard. This work was coupled to process and outcome evaluation within ENC and the professional circus community within Montreal. The findings of this research and other concurrent studies, teamed with the clear utility of the measures implemented, resulted in substantive policy and programmatic adaptations.

Manuscript 1 revealed that circus student-artists reported better sleep hygiene than self-reported in their athlete counterparts. Overall, a relatively small portion of student-artists had difficulties with sleep and the issues that were present were rather individual. This information resulted in the presentation of workshops for student-artists and teachers with specific recommendations for individual sleep deficits. Informational cue cards were also developed and distributed to the staff and student-artists. Further, the sleep hygiene assessments utilized in this research were adapted and utilized in professional circuses

(Cirque du Soleil and Cirque Eloize), along with an investment into sleep and fatigue science software.

As a result of the findings from manuscript 2, the assessment of body composition has become routine practice in the circus student-artists at ENC. An identical method of body composition assessment is also used at Cirque du Soleil during intake, progress, and return-to-show evaluations. The information gained through the body composition assessments has permitted an increase in nutritional consultation at Cirque du Soleil and, as previously mentioned, at ENC.

The value of the measurements utilized in manuscript 3 was immediate in that it afforded characterization of psychological status in a developing circus artist context. The results of this work revealed a complex interaction of psychological parameters and highly individualistic challenges. The findings led to the implementation of available weekly hours with a psychology counsellor and the development of an in situ circus medicine clinic at ENC. Prior to this research, only athletic therapy services were internally available at ENC. It appears that the role of measurement was also one of de-stigmatization. Positively, the scheduled hours of the counsellors led to routine utilization of services by the student-artists and increased willingness to discuss their use of the services. Further, a performance psychologist is now part of the research team at CRITAC and is currently undertaking work to further enhance the performance psychology of the student-artist population at ENC.

An interesting finding from the CDCQ used in manuscript 3 revealed that nutrition was ranked as a substantial challenge for the student-artists. The text-based commentary associated with the challenges survey (not published in this thesis) revealed a desire of the student-artists to understand how to cook for themselves and to better understand performance fueling. This has led to the development and implementation of workshops related to performance fueling and greater access to nutritionists. In fact, ENC has stated a goal of hiring a full-time nutrition consultant by Fall 2020.

The CDCQ, due to its overlap in timing with the federal legalization of marijuana, also revealed that the student-artists stated a strong curiosity regarding the impact of marijuana on performance and safety. While the reported substance-use challenge in the school was low, given the curiosity of the student-artists, substance use, misuse and abuse workshops for student-artists and staff were developed and delivered. These evidence-based workshops were very popular and have led to the development of rational approaches to dealing with the legalization of marijuana and contributed to the development of a 1.5-year project centered on the creation of a comprehensive Safety and Performance Framework for ENC.

The examination of the injury database in manuscript 4 was valuable in demystifying the injury conditions at ENC and shed light on possible interventional strategies for prevention and enhanced rehabilitation processes. The initial role of examination of the database was to simply characterize the injuries at ENC in terms of prevalence based upon site and type of injury, mimicking injury studies from sport. This characterization led to the realization

that standard methods of reporting injuries in sport contexts over large time windows was perhaps masking findings. This resulted in analyzing the injury rates (hazard ratios) per week, rather than by month, by season, or by semester as typically undertaken in sport contexts. In so doing, patterns in injury rates that were previously undocumented were detected. One of the key findings from this work was a statistically significant and elevated rate of injury for the three weeks post-return from the winter vacation, relative to the rates for the training year and the subsequent month of February. This finding led to formal discussions with staff, leading to increased knowledge and understanding by all related to this important issue. Further, we developed workshops for the student-artists to help them better prepare during the three-week vacation by providing evidence-informed training practices to maintain physical competencies and practice strategies to mitigate erosion in technical abilities. A direct takeaway from one of the workshops was the creation of a performance core training document which was released and is now used worldwide for many sports and in many circus contexts.

In circus, the motor competence of the artists is a primary attraction from the audience's point of view. A 2011 paper published on the injury rates of professional circus artists revealed an increased rate of injury after prolonged days off[51]. The study explored a sport theory of "cumulative fatigue" and postulated that injuries would diminish following breaks from training. The opposite effect was observed, however, leading the authors to conclude that the increased injury rate post-break could be due to a loss of timing in precision-based acts (diminution of motor competence with time away) and/or hesitation on the part of the artists to report an injury immediately prior to a break, knowing that the injury may heal

on its own during the time away from training[51]. Our finding of a three-week prolonged elevation in injury rate, with nearly equal proportions of short (<4 weeks) and long (>4 weeks) treatment durations, allowed us to develop a list of potential causative factors to explore through translational research and through circus practice action. Interestingly, the spike in injuries post-break coincided with low daily challenge, state anxiety, and training load levels. However, the increased injury rate post-break did align with a maladaptation in body composition (decreased muscle mass and elevated fat mass).

While knowledge translation outcomes have resulted from each specific manuscript, many important outcomes have resulted from the general awareness of circus research raised by this thesis. At ENC, the comprehensive battery of longitudinal research evaluations that were deployed in this study resulted in numerous policy and practice changes. The completion of these projects was a significant contributor to the establishment of the CRITAC and its baseline funding of $1 million per year, and the hiring of numerous staff devoted to the topical matters discussed in this thesis. This thesis has also led to numerous invited presentations at circus network meetings and conferences and has aided in the development of the Circus Arts Research Platform (CARP). Additionally, this thesis led to the creation of a formal student-artist evaluation process which is used to inform members of the first-ever integrated support team (medical, paramedical, psychology, nutrition, strength and conditioning, technical, and artistic staff) at ENC to guide the school's periodization plan and individualized training programs.

The results of this thesis have also heavily influenced the professional ranks of the circus industry. As a direct result, Cirque du Soleil implemented an online sport science platform (CoachMePlus) to collect, analyze and visualize data regarding sleep, fitness, daily stress, workload, and body composition. The importance of using data to inform practice at Cirque du Soleil also resulted in the first-ever hiring of a Performance Conditioning Specialist at Cirque du Soleil's International Headquarters, the creation of internships for kinesiologists, and influenced the development of the Research Advisory Group.

At another professional circus company, Cirque Eloize, the assessment tools from this thesis were deployed to all performers and technicians using an online assessment tool. Additionally, EnPiste, which is the professional union of circus performers and technicians and coaches, has opted to develop workshops and online knowledge to aid in the careers of their registered members.

Practical Implications

The present thesis provides practical implications for circus artists, researchers, coaches, and performance science and medicine practitioners, which are listed below:

- The majority of circus student-artists achieved acceptable sleep duration, quality, and latency. For those who did not, however, individualized sleep hygiene strategies

should be developed.

- Student-artists of different disciplines are characterized by different body composition profiles. As a result, physical preparation, technical and artistic, and medical personnel should aim to develop discipline-specific and, when possible, individualized training programs to optimally enhance the physical performance of artists.

- The magnitude of daily challenges and state anxiety scores covaried with fatigue. Further, daily challenges, state anxiety, perceived coping, and fatigue all fit within a gradient of non-specific psychological distress (K6). Prior to entering periods of high training load and concomitant fatigue, individualized interventions targeting the addition of coping resources and strategies should be presented to student-artists to reduce daily stress and state anxiety levels. This approach aligns with the stress process model and social ecological model of resilience.

- Injury rates increased during the first three weeks of training upon return from the winter holiday break. Staff should provide student-artists with individualized nutritional, physical, and mental performance strategies to minimize as many putative factors of injury as possible and to prevent de-conditioning over the three-week break. Additionally, a period of re-training should be implemented within the first few weeks of return to training to gradually progress student-artists to pre-break training loads.

While direct extrapolation of these practical implications to performing artists outside of circus and to high-performance sport environments warrants a degree of caution, they may, at minimum, provide direction to future research considerations within these populations. For instance, this thesis shows that desirable sleep hygiene is attainable in high-performance environments and should be studied in sport and the performing arts. Also, the use of a repeated measures longitudinal assessment design demonstrated the importance of measuring key parameters throughout a training cycle and suggests that in high-performance environments longitudinal measurements should be made. And, the results of this thesis support the use of interventional approaches aligned with the stress process model and social ecological model of resilience, which may have suitability in sport and performing arts settings where individualized interventional approaches to psychosocial parameters should be adopted.

Future Research Directions

This thesis is the first characterization of sleep, body composition, and daily challenges, as well as the putative mechanisms of injury following a prolonged break from training in elite circus student-artists. While this thesis provides valuable information, further research is needed to develop a comprehensive understanding of physical, physiological, and psychological characteristics of professional and developing circus artists. Future research should:

- Characterize additional physical, physiological, and psychological factors that have yet to be assessed in a circus-specific context (ex. fitness, nutrition, sleep chronotype)

- Examine the relationships among sleep, body composition, psychological factors, and workload to performance, daily health, and injury

- Conduct interventional studies to assess the effect of general and individually-tailored strategies and interventions on health and performance

- Repeat the studies which make up this thesis in additional high-performance sport and performing arts (e.g. dance) development environments and professional contexts.

- Aim to develop a holistic long-term development model for circus artists using modern approaches to training

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*excludes references from manuscripts as each manuscript has its own reference list

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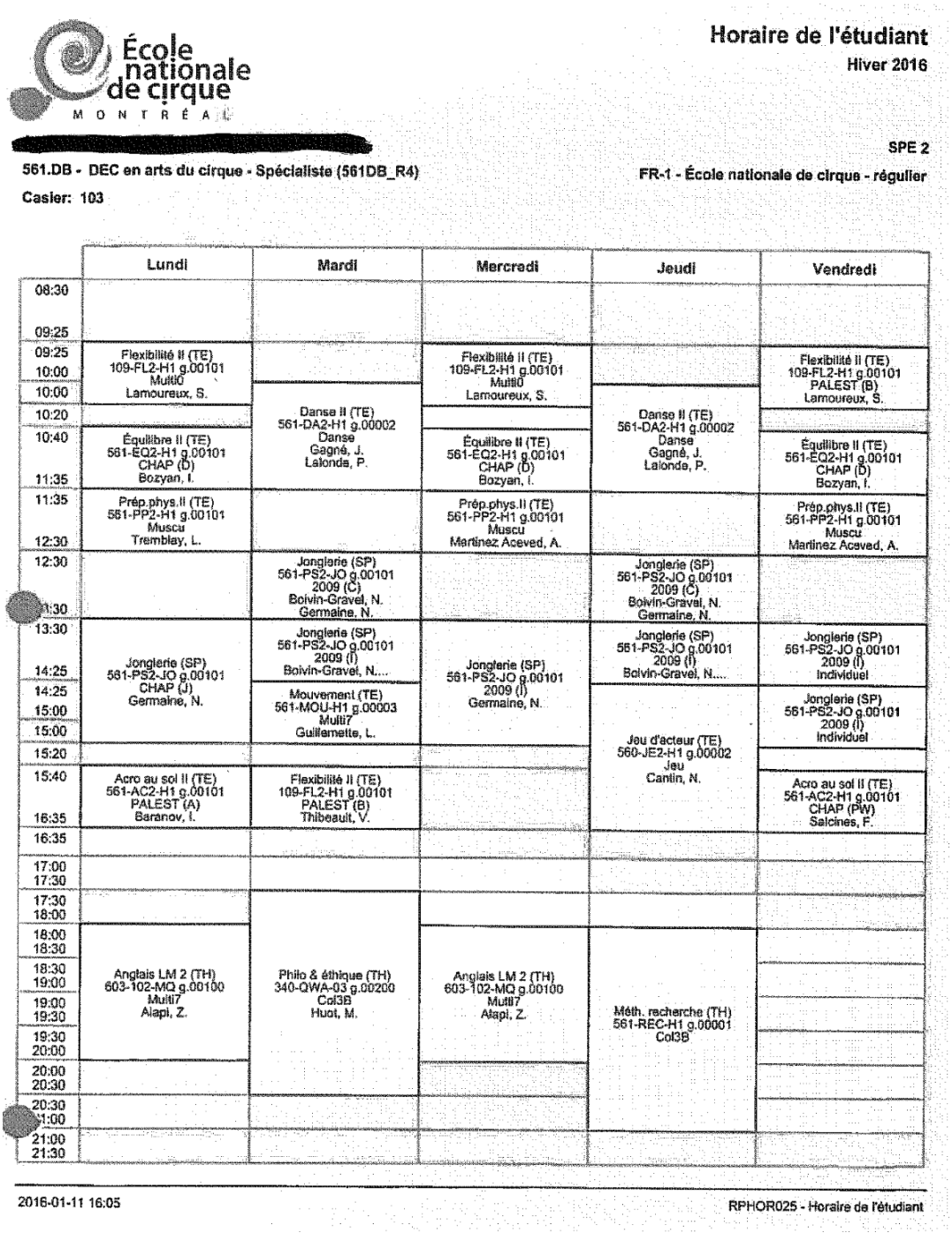
Appendices

Appendix 1: Sample Student-Artist Schedule



École nationale de cirque
MONTRÉAL

Horaire de l'étudiant
Hiver 2016

[redacted]

SPE 2

561.DB - DEC en arts du cirque - Spécialiste (561DB_R4)

FR-1 - École nationale de cirque - régulier

Casier: 103

	Lundi	Mardi	Mercredi	Jeudi	Vendredi
08:30 09:25					
09:25 10:00	Flexibilité II (TE) 109-FL2-H1 g.00101 Multi0 Lamoureux, S.		Flexibilité II (TE) 109-FL2-H1 g.00101 Multi0 Lamoureux, S.		Flexibilité II (TE) 109-FL2-H1 g.00101 PALEST (B) Lamoureux, S.
10:00 10:20		Danse II (TE) 561-DA2-H1 g.00002 Danse Gagné, J. Lalonde, P.		Danse II (TE) 561-DA2-H1 g.00002 Danse Gagné, J. Lalonde, P.	
10:40 11:35	Équilibre II (TE) 561-EQ2-H1 g.00101 CHAP (D) Bozyan, I.		Équilibre II (TE) 561-EQ2-H1 g.00101 CHAP (D) Bozyan, I.		Équilibre II (TE) 561-EQ2-H1 g.00101 CHAP (D) Bozyan, I.
11:35 12:30	Prép.phys.II (TE) 561-PP2-H1 g.00101 Muscu Tremblay, L.		Prép.phys.II (TE) 561-PP2-H1 g.00101 Muscu Martinez Aceved, A.		Prép.phys.II (TE) 561-PP2-H1 g.00101 Muscu Martinez Aceved, A.
12:30 13:30		Jonglerie (SP) 561-PS2-JO g.00101 2009 (C) Boivin-Gravel, N. Germaine, N.		Jonglerie (SP) 561-PS2-JO g.00101 2009 (C) Boivin-Gravel, N. Germaine, N.	
13:30 14:25	Jonglerie (SP) 561-PS2-JO g.00101 CHAP (J) Germaine, N.	Jonglerie (SP) 561-PS2-JO g.00101 2009 (I) Boivin-Gravel, N....	Jonglerie (SP) 561-PS2-JO g.00101 2009 (I) Germaine, N.	Jonglerie (SP) 561-PS2-JO g.00101 2009 (I) Boivin-Gravel, N....	Jonglerie (SP) 561-PS2-JO g.00101 2009 (I) Individuel
14:25 15:00		Mouvement (TE) 561-MOU-H1 g.00003 Multi7 Guillemette, L.		Jeu d'acteur (TE) 560-JE2-H1 g.00002 Jeu Cantin, N.	Jonglerie (SP) 561-PS2-JO g.00101 2009 (I) Individuel
15:00 15:20					
15:40 16:35	Acro au sol II (TE) 561-AC2-H1 g.00101 PALEST (A) Baranov, I.	Flexibilité II (TE) 109-FL2-H1 g.00101 PALEST (B) Thibeault, V.			Acro au sol II (TE) 561-AC2-H1 g.00101 CHAP (PW) Salcines, F.
16:35 17:00					
17:00 17:30					
17:30 18:00					
18:00 18:30	Anglais LM 2 (TH) 603-102-MQ g.00100 Multi7 Alapi, Z.	Philo & éthique (TH) 340-QWA-03 g.00200 Col3B Huot, M.	Anglais LM 2 (TH) 603-102-MQ g.00100 Multi7 Alapi, Z.	Méth. recherche (TH) 561-REC-H1 g.00001 Col3B	
18:30 19:00					
19:00 19:30					
19:30 20:00					
20:00 20:30					
20:30 21:00					
21:00 21:30					

2016-01-11 16:05

RPHOR025 - Horaire de l'étudiant

Appendix 2: Sleep & Fatigue Survey

Sleep & Fatigue

ID Code or Name _____

1. How fatigued do you feel right now? Mark an "X" in the circle.

Not at all • • • • • • • • • • • I am exhausted

2. Describe how you felt overall during the past 7 days (pick the best response).

Please only complete this question on the last day of the week.

- I have little to no fatigue
- I was challenged but I am recovering well
- I can feel the workload accumulating on me
- I am not recovering and need to rejuvenate

3. Sleep Log

DAY 1 _____ (date)

What time did you **FALL ASLEEP** last night? _____ (11:00 pm)
What time did you **WAKE UP** today? _____ (8:00 am)
Did you **NAP** yesterday? (circle) Y N

When you woke up, how did you feel?

Refreshed • • • • • • • • • • • Exhausted

How well did you sleep?

Very well • • • • • • • • • • • Poorly

Did you have trouble falling asleep?

No trouble • • • • • • • • • • • Was difficult

This section is repeated for an additional 6 days

Appendix 3: mfBIA Sample Output

InBody230

Name(I.D.)	Gender	Age	Height	Date	Time
TS7956	Male	30years	5ft. 8.9in.	01.26.2009	10:39:46

BIOSPACE

Body Composition

	Values	Lean Body Mass	Weight
Total Body Water	106.3 lbs.	145.3 lbs.	252.7 lbs.
Dry Lean Mass	39.0 lbs.		
Body Fat Mass	107.4 lbs.		

Body Composition

Body composition testing is the process of measuring the components of your body, in short what you're made of. Weight alone is not a clear indication of good health because it does not distinguish how many pounds are fat and how many pounds are lean body mass. By regularly monitoring your Body Fat, and Muscle Mass or Muscular Development, you can understand how your diet, lifestyle and exercise regime are influencing your body composition. Knowing what's working for you can help you target and reach your wellness, appearance and longevity goals.

Body Composition Analysis

	Under	Normal	Over
Weight			252.7 lbs.
Skeletal Muscle Mass			83.3 lbs.
Body Fat Mass			107.4 lbs.

Body Composition Analysis

What we're made of impacts our health, appearance and our capabilities. Too much Body Fat increases our risk of developing diseases such as diabetes, heart disease and cancer. Carrying too much weight places undo strain on our joints, heart and vital organs. Ideally, the Skeletal Muscle Mass graph to the left should reach or surpass the normal range and the Body Fat Mass graph should be falling within the Normal Range.

Obesity Analysis

	Under	Normal	Over
BMI Body Mass Index (kg/m²)			37.4
PBF Percentage of Body Fat (%)			42.5

$BMI = \frac{\text{Weight, kg}}{\text{Height}^2, \text{m}^2}$ $PBF = \frac{\text{Fat}}{\text{Weight}} \times 100$

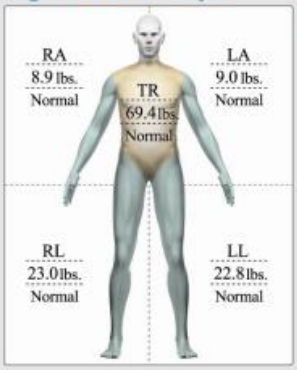
BMI Body Mass Index ☐ Under ☐ Normal ☑ Over

PBF Percentage of Body Fat ☐ Under ☐ Normal ☑ Over

Obesity Analysis

BMI isn't a measurement but a calculation based on your height and weight. A BMI over the normal range can indicate a weight problem, or a degree of obesity. Individuals with large amounts of muscle mass for their height may also have a BMI over the normal range; this is not indicative of obesity or a health risk. Percentage of Body Fat is a measured component of your actual body composition, PBF is the percentage of your total weight that isn't muscle, bone or excess fluid. PBF is a more accurate means of assessing degrees of obesity or degrees of fitness.

Segmental Lean Analysis



Segmental Lean Analysis

Use this section to understand how your muscle mass is distributed throughout your body. Your segmental distribution could indicate that you have maintained or developed muscle mass proportionately. You may discover that you have a tendency toward a disproportionate amount of muscle in your legs or your trunk and arms. Genetically there are inherent tendencies toward more or less musculature in any of these areas. It's true that you can't "spot lose" fat but you can develop or maintain certain muscles by using them more.

Impedance

Z	RA	LA	TR	RL	LL(Ω)
20 kHz	291	289	26.7	237	239
100 kHz	254	254	22.0	206	209

Body Fat & LBM

Body Fat	- 81.8 lbs.
LBM	0.0 lbs.

Fat : + (need more body fat mass)
- (lose body fat mass)

LBM : +(need more lean body mass)
0.0 lbs.(maintain current LBM)

Basal Metabolic Rate

BMR	1793 kcal

The BMR is the minimal number of calories needed to sustain life at a resting state. BMR is directly correlated with Lean Body Mass. With age muscle depletes and BMR steadily decrease.

Appendix 4: Circus Daily Challenges Questionnaire (CDCQ)

Circus Daily Challenges

ID Code _____

Please rank the current challenges in your life.

	Not a challenge at this time	Little challenge	Moderate challenge but I can manage	Moderate challenge, having difficulty managing	High challenge but I can manage	High challenge, having difficulty managing
Academic work	☐	☐	☐	☐	☐	☐
Financial	☐	☐	☐	☐	☐	☐
Relationships (family)	☐	☐	☐	☐	☐	☐
Relationships (friends)	☐	☐	☐	☐	☐	☐
Relationships (romantic)	☐	☐	☐	☐	☐	☐
Relationships (staff, teacher, coach, etc)	☐	☐	☐	☐	☐	☐
Demands of the school (schedule, etc)	☐	☐	☐	☐	☐	☐
Language / Culture	☐	☐	☐	☐	☐	☐
Physical Preparation	☐	☐	☐	☐	☐	☐
Technical Skill (progression, level, achieving objectives)	☐	☐	☐	☐	☐	☐
Artistic Skill (personal, objectives, performance)	☐	☐	☐	☐	☐	☐
Sleep	☐	☐	☐	☐	☐	☐
Nutrition	☐	☐	☐	☐	☐	☐
Coping emotionally	☐	☐	☐	☐	☐	☐
Injury	☐	☐	☐	☐	☐	☐
Substance misuse and abuse	☐	☐	☐	☐	☐	☐

Can you briefly describe what is your biggest challenge?

_____
_____

Tell us about the most important thing you do that helps you cope?

_____
_____

What is something you could do, that you aren't doing, to help you cope?

_____
_____

Let's check in, OVERALL what is your anxiety level?

- o I have no anxiety
- o I have low anxiety
- o My anxiety is moderate but I am managing
- o My anxiety is moderate and is having a negative impact on me
- o My anxiety is high but I am managing
- o My anxiety level is high and is having a negative impact on me

Tell us about your mental ability to handle challenges?

	1	2	3	4	5	6	7	
Lacking	☐	☐	☐	☐	☐	☐	☐	Excellent

Tell us about your physical ability to handle challenges?

	1	2	3	4	5	6	7	
Lacking	☐	☐	☐	☐	☐	☐	☐	Excellent

Do you have supports and resources to help you outside of the school?

- o Not really
- o Yes, but not enough
- o Yes, fair to good
- o Yes, very good

Do you have supports and resources to help you inside of the school?

- o Not really
- o Yes, but not enough
- o Yes, fair to good
- o Yes, very good