The relationship between differential and session ratings of perceived exertion with heart-rate derived measures of internal load in contemporary dance: An observational study

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Declaration

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This research thesis entitled ‘The relationship between differential and session ratings of perceived exertion with heart-rate derived measures of internal load in contemporary dance: An observational study’, is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

Principal Supervisor: Rob Moran

CANDIDATE’S DECLARATION

I confirm that:

- This thesis represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

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# Abbreviations and symbols

<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>RPE</td>
<td>Rating of perceived exertion</td>
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<tr>
<td>sRPE</td>
<td>Session rating of perceived exertion</td>
</tr>
<tr>
<td>session RPE</td>
<td>Session rating of perceived exertion (a rating for the entire session)</td>
</tr>
<tr>
<td>RPE-T</td>
<td>Differential session rating of perceived exertion for cognitive technical demand</td>
</tr>
<tr>
<td>dRPE</td>
<td>Differential session ratings of perceived exertion (ratings of different components of sRPE)</td>
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<tr>
<td>RPE-B</td>
<td>Differential session rating of perceived exertion for breathlessness</td>
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<tr>
<td>RPE-A</td>
<td>Differential session rating of perceived exertion for arms</td>
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<tr>
<td>RPE-L</td>
<td>Differential session rating of perceived exertion for legs</td>
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<tr>
<td>sRPE-TL</td>
<td>Training load</td>
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<tr>
<td>dRPE-T</td>
<td>Differential of training load – cognitive/technical demand</td>
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<tr>
<td>dRPE-B</td>
<td>Differential of training load – breathlessness</td>
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<tr>
<td>dRPE-A</td>
<td>Differential of training load – arms</td>
</tr>
<tr>
<td>dRPE-L</td>
<td>Differential of training load – legs</td>
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<tr>
<td>TRIMP</td>
<td>Training impulse</td>
</tr>
<tr>
<td>ACC</td>
<td>Accident Compensation Corporation</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
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<tr>
<td>CR</td>
<td>Category Ratio</td>
</tr>
<tr>
<td>CR-10</td>
<td>Borg’s Category Ratio 10 point scale</td>
</tr>
<tr>
<td>CR-100</td>
<td>Borg’s Category Ratio Centimax 100 point scale</td>
</tr>
<tr>
<td>%HRpeak</td>
<td>Heart rate expressed as a percentage of the maximum heart rate</td>
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<tr>
<td>DAFT</td>
<td>Dance specific Aerobic Fitness Test</td>
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Introduction to thesis

Dancing has always been a part of human history and movement culture (Brinson & Dick, 1996). In dance, the body is the medium for expression and dance is found in every human society (Laland, Wilkins, & Clayton, 2016). Prehistoric depictions of dance from south-eastern Europe and Egypt date from as early as 8000 BC and as early as 9000BC in India (Kassing, 2007; Pande & Varadpande, 1987). Within the historical record, dance is known to have been an integral part of ancient Greek, Egyptian and Chinese societies (Angioi, Metsios, Koutedakis, & Wyon, 2009; Wang, 1985). In New Zealand, dance was, and remains central to Māori culture (Bradshaw, 2015). Traditional Māori dance has become embedded in New Zealand’s sporting culture and national identity through performance of haka prior to sporting events (Schultz, 2011a). The Māori renaissance has seen the resurgence of many traditional dances as evidenced in the explosive growth of kapa haka groups around the country (Bradshaw, 2015). Informed by this rich cultural heritage, New Zealand has a unique and vibrant dance scene. A number of professional dance companies such as Black Grace, Atamira, Okareka and Mau have blended traditional forms with more modern and contemporary approaches creating choreographies which are distinctive and unlike anything else in the world.

Dancers risk injury in the pursuit of their art and unfortunately, injury prevalence is high (Hincapié, Morton, & Cassidy, 2008). The need for applying a comprehensive sports injury prevention approach to dance has been recognised (Marijeanne Liederbach, Hagins, Gamboa, & Welsh, 2012). Indices of workload have been identified as an important risk-factor for injury (Hulin et al., 2014). Consequently, injury prevention in sports has been enhanced by the ability to quantify and monitor the athlete’s workload (Windt & Gabbett, 2017). This thesis examines whether the approaches for quantifying workload used in sport can be applied to dance by investigating the relationship between subjective (ratings of perceived exertion) and objective (heart-rate measures) methods for quantifying workload. The primary aim was to investigate the relationship of perceived exertion with heart-rated derived measures of workload as a criterion measure, across several companies of dancers with different levels of experience. It is important to establish how appropriate these different subjective measures are in dance, before applying them in future dance
injury prevention research. The subjective methods investigated were the session rating of perceived effort (sRPE) and four differentials of it (dRPE). Session RPE is a convenient method for practical application because all it requires is that the athlete rate the intensity of their training session using a simple scale. This ease of application is why it has received so much attention in sports studies (Foster et al., 2001). Recently, dRPE has been proposed as a more sensitive tool than sRPE because it separates a single rating into differential ratings (McLaren, Graham, Spears, & Weston, 2016). These differentials represent different dimensions of the perception of exertion and reflect different biochemical and biomechanical pathways contributing to the overall workload (Vanrenterghem, Nedergaard, Robinson, & Drust, 2017). In essence, dRPE provides more detailed information. In the study reported in this thesis, the objective measures of workload were two heart rate derived methods for quantifying workload, Edwards’ and Banister’s Training Impulse (or ‘TRIMP’) which are commonly used as criterion measures in validation studies of sRPE in sport (Haddad, Stylianides, Djaoui, Dellal, & Chamari, 2017). To the author’s knowledge, this is the first study to investigate dRPE in dance.

Thesis Structure

This thesis is divided into three sections. Section I is a review of the literature to provide the background information necessary to understand the context and relevance of the thesis topic. Section II is a manuscript reporting a study addressing the relationship between session and differential ratings of perceived effort and heart rate derived measures of internal load, and is formatted in the style required for submission to the Journal of Dance Medicine and Science. Additional and supplementary material including ethics documentation is included in Section III.
SECTION I – LITERATURE REVIEW
1.1 Literature review overview

The review commences with a description of contemporary dance in terms of artistic and physiological parameters and will be shown to be a highly variable form of dance; making its categorisation and the generalisation of findings challenging. The first part of the review will place the investigation of workload\(^1\) within the context of injury prevention as this is where the potential for monitoring workload might have the greatest impact on the dancer’s wellbeing. Intensity will be demonstrated to be the key variable in terms of understanding the overall workload a dancer undertakes when training in dance class. This is important, because of the relationship between workload and injury, (Windt & Gabbett, 2017). Although dancers experience traumatic injuries (Hincapié et al., 2008), in this thesis overuse injuries will be emphasised because they are the most common injury in contemporary dance (Jacobs, Hincapi, & Cassidy, 2012; Kenny, Palacios-Derflingher, Whittaker, & Emery, 2018; Lee, Reid, Cadwell, & Palmer, 2017), and are also considered, at least theoretically, to be entirely preventable (Drew & Purdam, 2016). This type of injury is currently thought to be the consequence of errors in the administration of workload (Gabbett, Kennelly, et al., 2016). Thus, the prevention of overuse injury is reliant on the ability to quantify and monitor workload. The second part of this review will critically discuss different methods for quantifying workload. To date, it appears that just one study has investigated sRPE in dance in a single population of dancers (Jeffries, Wallace, & Coutts, 2017). These authors concluded that sRPE was a valid tool for quantifying workload in dance and their study will be reviewed in detail. The appropriateness of different objective physiological methods for determining workload and their use as criterion measures for sRPE and dRPE will be evaluated. This will include a discussion of why dRPE is a potentially useful addition to sRPE.

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\(^1\) Workload in the sports literature is also frequently referred to as ‘training load’. In dance this could be substituted with terms such as ‘rehearsal load’, ‘class load’, or ‘performance load’. To keep a consistency between the sport literature cited in this review, the conventional term ‘training load’ and ‘workload’ will be used in this thesis.
1.2 Dance definitions and context

1.2.1 Description of contemporary dance

Contemporary dance is often considered to be synonymous with modern dance (Needham-Beck, 2017). This is perhaps because both can be seen to be a reaction to ballet, which preceded them historically. Modern dance and contemporary dance are both predominantly 20th century phenomena, and evolved as a rejection of the romantic idealism of ballet and replaced its refined representational aesthetic with a raw emotional and more abstract expression (Schultz, 2018). However, modern dance and contemporary dance are not entirely synonymous. Whereas ballet and modern are codified forms of dance with a discrete vocabulary, contemporary dance distinguishes itself from both of these by a refusal to codify its movements (Long, 2002). Instead, contemporary dance choreographers methodically research and develop new movement vocabulary with the intention of it being viewed as art (Stevens & McKechnie, 2005). Its “stylistic features are constantly changing because its production is incessantly evolving through what Strauss (2012, p.16) describes as a process of “experimentations, rejections and ground breakings”. Contemporary dance therefore has a high degree of variability in its physical expression. In fact, equating contemporary dance with movement has itself been challenged. Just as Marcel Duchamp’s, ready-made sculpture “Fountain”, (a urinal), questioned notions of the production of art (Hubregtse, 2009) or John Cage with his piano piece where not a single audible note was played (Kahn, 1997), some contemporary dance choreographers have questioned the necessity for movement in its production and have reduced or removed physical expression entirely from it. This development within contemporary dance has been termed ‘non-dance’ and is perhaps best exemplified in the work Nom Donné par l’auteur by the influential French choreographer Jerome Bel (Abrams, 2008). In this choreography, the dancers do not dance in the conventional sense, they only move various household objects around the stage (Lepecki, 2006). Contemporary dance in New Zealand has not embraced the non-dance movement, with the majority of its contemporary companies tending towards virtuosic displays of physical expression, perhaps due to the influence of the NZ choreographer Douglas Wright. As an ex-gymnast, Wright’s brand of physicality “seemed to defy gravity and ordinary human strength (Schultz, 2011a, p. 238). The
Illustrated History of Dance in New Zealand also notes the energy apparent in New Zealand’s dancing tradition (Werner, 2008). Another reason posited for the high degree of physicality is that in order to win the respect of New Zealand’s sport enthusiastic audiences, dance needed to rival or exceed the physicality found on the sports-field (Schultz, 2011b).

1.2.2 Physiological categorisation of dance

In physiologic terms, dance is frequently described in the dance science literature as an intermittent, diverse, complex, and non-steady state activity (Angioi et al., 2009; Needham-Beck, 2017; Redding & Wyon, 2003; Wyon, Redding, Abt, Head, & Sharp, 2003; Wyon & Redding, 2005). Dance has also been shown to use both aerobic and anaerobic energy systems of the body (Beck, Redding, & Wyon, 2015). Dance has also been categorised as high-intensity (Wyon & Koutedakis, 2013). However, intensities have been shown to be variable and are more accurately described as ranging from moderate to high (Needham-Beck, 2017) depending on the nature of the movement material. The intensity of contemporary dance classes has been shown to be variable with the warm up phase being of moderate intensity (Wyon & Redding, 2005). Dance classes have been shown to be an insufficient stimulus to produce aerobic and anaerobic adaptation and therefore does not prepare the dancer for the demands of performance where the energy demands are higher (Dahlström, 1997; Wyon, Head, Sharp, & Redding, 2002; Wyon, Abt, Redding, Head, & Sharp, 2004; Wyon & Redding, 2005). If the workload of contemporary dance class and performance could be conveniently quantified, sudden increases in intensity might become more apparent and adjustments made to mitigate against sudden increases in workload. Workloads could be organised in more systematic ways and could be gradually increased in a manner the dancer could adapt to and that would prepare them appropriately for performance avoiding the sudden changes in load known to be associated with higher risk of overuse injury (Gabbett, Hulin, Blanch, & Whiteley, 2016).
2.1 Overview of dance injuries

2.1.1 Dancers’ attitudes to injury and pain
Most dancers do not want to stop dancing because of injury, or have an injury hamper their ability to perform (Jacobs et al., 2017). A career ending injury is the professional dancer’s greatest fear (Krasnow, Kerr, & Mainwaring, 1994). However, many dancers continue to dance despite being injured and, because injuries are common, there can be a culture where continuing to perform while injured is expected despite the potential for negative long-term health consequences (Rip, Fortin, & Vallerand, 2006; Russell, 2013). Many consider pain to be a part of being a dancer and dancers have been shown to have a higher pain threshold and pain tolerance when compared to non-dancers (Jacobs et al., 2017; Russell, 2013). Of particular concern, and a confounder in understanding the true extent of the problem, is the failure of many professional dancers to report their injuries (Jacobs et al., 2017). Equally concerning is a reluctance on the part of dance students to seek medical management due to the fear of being told to cease dancing (Baker, Scott, Watkins, Keegan-Turcotte, & Wyon, 2010; Liederbach et al., 2012).

2.1.2 Dance injury prevalence, incidence and injury sites
The prevalence of injuries appears to be high across all genres of dance (Allen, Ribbans, Nevill, & Wyon, 2015; Jacobs et al., 2017). A recent systematic review of dance injuries estimates an incidence of 1.33 injuries per 1000 dance hours with an average of 1.93 injuries per year per dancer (Allen et al., 2015). Another systematic review looking specifically at injury amongst pre-professional dancers reported an incidence between 0.77 and 4.71 injuries per 1000 dance hours (Kenny, Whittaker, & Emery, 2016). A third systematic review reveals that, across multiple dance genres, the most common injury sites were the ankle/foot and knee (Cardoso et al., 2017). Contemporary dancers are known to have higher rates of injury in the lower back and shoulders due to the specific physical demands of their genre (Liederbach, Dilgen, & Rose, 2008; Sides, Ambegaonkar, & Caswell, 2009).

2.1.3 Overuse injuries in dance
In their systematic review of musculoskeletal injuries and pain in dance, Hincapié et al. (2008) found that overuse injuries were the most prevalent type of dance injury
and were most often located in the lower-limb or lower back. This type of injury also appears to be the most prevalent among the contemporary dance population (Bronner, Ojofeitimi, & Rose, 2003; Bronner & Wood, 2016; Kenny et al., 2018).

However, it is important to state that all the systematic dance injury reviews mentioned here note that their conclusions are limited by the quality and quantity of the dance injury studies available for review. For example, each of these systematic reviews included between 29 (Hincapié et al., 2008), 47 (Allen et al., 2015), and 12 studies (Cardoso et al., 2017) thus indicating the general lack of good quality studies in the area of dance injury epidemiology.

2.1.4 Dance injury studies and changes in workload

Despite numerous studies investigating the relationship between workload and injury in sports including in football (soccer) (Bowen, Gross, Gimpel, & Li, 2017), Australian football (Colby, Dawson, Heasman, Rogalski, & Gabbett, 2014) cricket (Hulin et al., 2014) and rugby league (Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016), there have been no dance injury studies quantifying the workloads of dancers and relating this to injury incidence. There are, however, studies that look at rates of injury with changes in the volume of work performed, and from these studies it is possible to infer how changing workloads might be a risk factor in injury aetiology. A number of studies have demonstrated higher rates of injury in the first three months of the year following a long holiday break (Baker et al., 2010; DiPasquale, Becker, Green, & Sauers, 2015; Kenny et al., 2018; Lee et al., 2017; Ojofeitimi & Bronner, 2011). Notably, the workload within the holiday period was not evaluated but was assumed to be much less. Comparing previous (chronic) workloads against current (acute) workloads has been useful in determining injury risk in sports (Gabbett, 2016; Windt & Gabbett, 2017).

Increases in injury incidence are also associated with exposure to new choreography and a high degree of repetition in the rehearsal period (Ojofeitimi & Bronner, 2011; Scialom, Goncalves, & Padovani, 2006). Anterior cruciate ligament injuries were shown to occur in greater number later in the day and later in the performance season and are likely to be the product of fatigue and overtraining (Liederbach et al., 2008). Fatigue and overtraining represent workloads that exceed the athlete’s ability to
recover (Halson, 2014). Fatigue and inferred changes in workload were recently implicated in injuries amongst part time dancers because they move between periods of minimal dancing to intense working periods and still continue to work their other non-dance jobs (Vassallo, Pappas, Stamatakis, & Hiller, 2018).

In a comparison between dance companies matched for training volume and training conditions, one company had considerably higher rates of anterior cruciate ligament injuries, (Meuffels & Verhaar, 2008) The authors speculated this difference may have been due to the differences in the amount of jumping between companies as differences in jump volume represent differences in workload.

2.1.5 Dance injuries in New Zealand
In New Zealand, according to the Accident Compensation Corporation (ACC), in the five-year period between July 2012 and July 2017 there were 40,000 new dance injury claims made, with a total financial burden of NZD $31 million dollars (ACC 2018a). However, the total burden is likely to be greater than ACC statistics indicate as they can only capture injuries that are a consequence of an accident and so by definition cannot include overuse injuries (ACC, 2018b). More detailed statistics for dancing injuries were requested from ACC and a break-down of injury by type and body part were provided. The most common injuries were soft-tissue injuries followed by bone fractures. The most common injury site, was the ankle followed by the knee, and this is a pattern aligning with Cardoso et al. (2017) who found the ankle/foot and knee to be the most common injury sites for professional dancers.

Unfortunately, there are no comprehensive epidemiological studies for dance injury in New Zealand. One study providing some limited insight into New Zealand dance injury epidemiology has been recently published. Lee et al. (2017) examined the incidence of dance injury in a tertiary dance training institution for pre-professionals studying ballet and modern dance. They found a prevalence of injury of 86.2% across the academic year. They used two injury definitions, “medical attention” as reported by the in-house physiotherapist and an “all complaints” obtained using a self-reporting questionnaire. Regarding modern dance an injury incidence of 2.17 injuries per 1000 hours of dancing was found. Lee et al. (2017) also found overuse injuries to be the most common injury type accounting for 59% of the reported injuries.
Furthermore, Lee et al. (2017) also found an increase in injuries occurring at the beginning of the year, following the summer break (2 months), and also following the semester breaks (2 weeks) suggesting an association between changes in workload and injuries. They also state the need for “examining training loads (acute and chronic)” for future research.

2.2 Standardising injury research

It is obvious that prevention of injury is more desirable than dealing with the consequence of injury (Russell, 2013). Unfortunately, progress towards preventive strategies has been hampered in both dance and sports alike because of a lack of standardisation in injury research. Lack of standardisation makes inter-study comparisons very difficult. In dance, this means it is difficult to estimate the true extent of the problem (Liederbach et al., 2012). In order to address this lack of standardisation there have been injury research consensus statements with guidelines for research emerging from different sport disciplines (Fuller et al., 2006; Fuller et al., 2007; Mountjoy et al., 2016). The International Association of Dance Medicine and Science consensus initiative for standard measures have produced recommendations for dance research, including injury research, (Liederbach et al., 2012). They suggest adoption of the injury prevention research model of van Mechelen (van Mechelen, Hlobil, & Kemper, 1992), as a framework for dance injury research (see figure 1.).
2.2.1 Injury Prevention Models

Figure 1. The injury prevention model of van Mechelen (van Mechelen et al 1992). A four stage sequence for injury prevention research.

Van Mechelen’s model provides a framework for research in four stages. The first stage is assessing the epidemiology of injury. This requires injury surveillance in the field so that the type and rate of injury are determined. The second stage is to understand what are the causal mechanisms of the injuries described in stage 1. Once the cause of the injury is understood preventative strategies can be considered and implemented, which is Stage 3. Step 4, is to test how effective the interventions have been by re-evaluating the effectiveness of the prevention initiatives by accessing post intervention epidemiological data. This model is therefore cyclic and requires ongoing surveillance so that the effects of any intervention can be seen. This model has been extended to include assessing the real-world context into which a preventive strategy is to be applied to determine barriers which may impede the adoption of these strategies (Finch, 2006).

2.2.2 Injury aetiology models

In considering the problem of injury in dancers, it is only recently that dancers are being considered as athletes at risk of injury due to the substantial amount of training they undertake to achieve high levels of technical artistry (Jacobs et al., 2017; Russell, 2013). Liederbach et al., (2012), in their consensus statement from the International Association for Dance Medicine and Science proposed using a modified version of
the classic sports aetiology injury model by Meeuwisse (Meeuwisse, 1994), to guide research (see figure 2).

![Figure 2](image.png)

**Figure 2.** Meeuwisse’s original injury aetiology model. Injury is seen as a consequence of the interaction of extrinsic and intrinsic factors. (Meeuwisse, 1994)

Meeuwisse’s model depicts a linear progression, where both intrinsic and extrinsic risk factors contribute to the likelihood of injury. Intrinsic risk factors can be seen to be the athlete’s individual attributes that affect injury risk and includes factors such as their state of fitness, biomechanical weaknesses, or skill level. Extrinsic risk factors are those in the environment to which the athlete is exposed, in the case of dance this might be the type of flooring or room temperature. However, Meeuwisse, Tyreman, Hagel, and Emery (2007) have expanded on this model in order to reflect a dynamic process which influences injury risk factors. (see figure 3). Injury risk in this model is considered to be non-linear, where the activity that the athlete undertakes can affect the risk factors themselves. Risk factors can change dynamically through exposure to the activity. Exposure is the time required to perform the activity and where the athlete is ‘exposed’ to the risk of injury. Exposure is not a measure of the intensity of activity. If exposure results in high levels of fatigue this could increase the risk of injury but conversely exposure might lower the risk if the athlete adapts sufficiently. Indeed, athletes train in order to provoke a positive adaption in order to improve their performance, but also, training can also be protective and reduce injury risk (Gabbett, 2016).
Figure 3. Meeuwisse’s recursive injury aetiology model where the interaction between intrinsic and extrinsic risk factors is dynamic. Intrinsic factors are not fixed but can change through exposure to external risk factors (Meeuwisse et al., 2007).

2.2.3 Injury definitions

There are three operational definitions used in sport epidemiology which have been suggested in a number of consensus statements in sports injury (Clarsen & Bahr, 2014; Fuller et al., 2006; Fuller et al., 2007; Timpka et al., 2014), these are: time-loss injury, medical attention injury, and ‘all complaints’. Time-loss means an injury that results in being unable to compete, practice or perform and represents time away from the activity and is usually measured in days. This definition fails to capture injuries where an athlete continues despite being injured and is therefore the least sensitive of the definitions. Medical attention is any injury where medical staff (eg physician, physical therapist, osteopath etc) were consulted and does not necessarily equate to time loss from participation. Medical staff should be able to classify the injury in terms of site, severity, and cause and therefore afford a better categorisation of injuries (Clarsen & Bahr, 2014). This definition is of course dependent on the availability and ease of access to medical staff. As previously stated dancers may be reluctant to report to a medical professional, and often dance through pain (Jacobs et al., 2017) and so this behaviour may result in underestimates of injury epidemiology relying on ‘medical attention’ definitions. The ‘all complaints’ definition is the most
sensitive and therefore likely to capture a broad range of injuries and a higher incidence but is likely to be less reliable because what constitutes a complaint is subject to interpretation (Ardern et al., 2016). The ‘all complaints’ definition has recently been used by Clarsen, Myklebust, and Bahr (2013) for a new injury surveillance method specifically designed to record the full burden of overuse injuries within the sporting population (Clarsen et al., 2013). In the process of validating their surveillance method, Clarsen et al. (2013) found that most overuse injury did not result in time-loss or require medical attention. This method uses self-reporting and thereby eliminates the need for third-parties and access to medical records. The inability of a time-loss definition to capture overuse injuries in sports epidemiology has been highlighted in a recent review (Neil, Winkelmann, & Edler, 2018).

Liederbach et al. (2012) noted the lack of consistency in injury definitions within the dance injury research. Liederbach et al. (2012) promote a time-loss medical attention definition for dance injuries in order to be consistent with the National Collegiate Athletic Association of the United States, which has used this definition for injury reporting for the past 30 years and argue that using a medical attention definition allows for more accurate and less ambiguous categorisation of injury as these can be documented reliably by medical staff. However, such is the prevalence of under-reporting amongst dancers that these authors acknowledge their definition might represent the ‘tip of the iceberg’ of dance injuries. Kenny et al. (2018) have recently drawn attention to this discrepancy between the suggested definition of injury for dance and where the actual burden of injury lies. They suggest in dance the all complaints definition is preferable. Kenny et al (2018) also found that most overuse injuries in dance were not captured with medical or time loss definitions.

### 2.2.4 Overuse injury definition

Timpka et al. (2014) propose a definition for overuse “repeated bouts of physical load without adequate recovery periods in association with sports training or competition”. These authors recognize that workloads without adequate rest is the key causal mechanism for overuse injuries. Overuse injuries may be the most prevalent in sports as they are in dance (Timpka et al., 2014). Unfortunately, there are a wide array of definitions of overuse injury used in sports injury epidemiology. This is a problem for inter-study comparison and for pooling studies to determine the full burden of injury.
To avoid this problem, Neil et al. (2018) suggest adopting a definition for “overuse” in sports injury epidemiology research. They define overuse injuries as “characterised by a mechanism of gradual onset and an underlying pathogenesis of repetitive microtrauma”. While this definition has utility in the reporting of injuries, from an injury aetiology standpoint, it does not describe what is the cause of overuse injuries.

2.3 Training and training load

The purpose of training is to improve performance outcomes and minimise or eliminate negative outcomes. Athletes and dancers train to improve within the parameters of their disciplines. Training can be considered the application of a dose-response relationship where the dose represents the activity with a sufficient level of physiological/psychological stress to provoke a positive response of adaptation to that activity (Lambert & Borresen, 2010). There are three key variables that influence performance outcomes: frequency of training, duration of training, and the intensity of training (Achten & Jeukendrup, 2003). ‘Exposure’ as a determinant of injury risk is usually measured in terms of frequency or duration (Lee et al., 2017) but does not include intensity and therefore doesn’t not capture fully the workload of the dancer. The combination of these three variables contributes to the training stimulus and is also termed the ‘training load’ (Foster et al., 2001). Training load can then be measured against performance outcomes which are either positive, such as increased physical capacities, or negative such as injury and fatigue.

Quantifying training load in sport has allowed an athlete’s training to be more closely monitored, and adjustments made to training prescription, thereby optimising adaptation and minimising undue fatigue (Elloumi et al., 2012; Halson, 2014). Periodisation of training load is conventionally considered to allow for greater adaptation by maximising recovery and training effects (Hoover, VanWye, & Judge, 2016). However, this approach is not widely used in dance despite the potential benefits (Wyon, 2010). In dance, the traditions of long rehearsals and working days may represent training loads that exceed those found in high level sports, with consequent fatigue, psychological distress and high rates of injury (Murgia, 2013).

Training load can be further subdivided into ‘external’ or ‘internal’ load (McLaren et al., 2018).
2.3.1 External training load
External training load is defined as the observable work the athlete undertakes in a given task or tasks. This can be measured using accelerometers which record the frequency and magnitude of movement (Boyd, Ball, & Aughey, 2011) and global positioning systems to monitor distance and speed when outside (Lovell, Sirotic, Impellizzeri, & Coutts, 2013). Jeffries et al. (2017) used accelerometers to quantify training load. Key movements in a specific discipline have also been suggested as appropriate for exploring external load (Haddad et al., 2017). Importantly, this is not a full quantification of the entire workload but does provide insight into key activities known to be particularly relevant to a specific sport. In throwing sports such as cricket and baseball the number of throws have been used as a measure of external load (Black, Gabbett, Cole, & Naughton, 2016). The use of accelerometers have enabled the accurate quantification of jump landing in gymnastics (Bradshaw & Hume, 2012; Simons & Bradshaw, 2016). Similar to gymnastics, the number of jump landings and accelerations over a specific threshold would give some indication of external workload in dance, but such approaches have not been widely adopted with only a few studies quantifying jump volume (Liederbach et al., 2006).

2.3.2 Internal training load
Whereas external load provides the stimulus for training adaptation different individuals may respond differently. An individual’s immediate response can be quantified as their internal training load. Internal training load has been defined as the psycho-physiological stress or impact from the external training load (McLaren, Smith, Spears, & Weston, 2017). Physiological stress can be further divided into centrally and peripherally driven stress (Vanrenterghem et al., 2017). Centrally driven physiological stress is a result of anaerobic and cardiovascular demands of training. Peripherally driven stress is due to the internal biomechanical loads on the muscles and joints (Vanrenterghem et al., 2017). Thus, there are multiple factors influencing internal training load which make it difficult to reduce it to a single target for measurement (McLaren et al., 2018). It is therefore important to investigate the relationship between different measures of internal training load (Robertson, Kremer, Aisbett, Tran, & Cerin, 2017). The ability to measure and monitor internal training load also provides a means to adjust external training load according to the needs of
the individual (Wallace, Slattery, Impellizzeri, & Coutts, 2014). One ‘size’ does not necessarily fit all.

2.4 The relationship between training load and injury

In considering sports injury aetiology, there is a clear association between training load and overuse injuries (Drew & Finch, 2016). Recently training load has been incorporated into a new definition of exposure to reflect its influence on injury. Training load is the manner in which an athlete is exposed to injury (Windt & Gabbett, 2016).

2.4.1 Overtraining and undertraining

Training loads that are too high have been linked to injury but more recently so too have training loads that are too low, a situation described as “undertraining” (Gabbett et al., 2016). Sudden increases in training load have been described as training ‘spikes’ and have been demonstrated to increase injury risk in cricket, (Hulin et al., 2014) and rugby (Hulin et al., 2015). Undertraining can result in deconditioning which can mean that training loads that were once acceptable become an injury risk (Drew & Purdam, 2016). In this way undertraining, like overuse injury, can be classified as a training load error (Gabbett, Kennelly, et al., 2016).

Despite the apparent association between injury and training load, the injury aetiology models of Meeuwisse et al. (2007) have not incorporated training load specifically. Recently, however, Windt and Gabbett (2017) have adapted Meeuwisse et al’s recursive injury model to explicitly reflect how training load might influence injury risk (Windt & Gabbett, 2017) (see figure 4).
2.4.2 An injury aetiology model that considers training load

The injury aetiology model of Windt and Gabbett (2017) recognises that from an injury risk perspective, the application of a training load exposes an athlete to external risk factors but which also concurrently modulates their internal risk factors, either positively or negatively. Importantly they note that workloads/training loads should be considered in light of previous loads described as the acute:chronic ratio. The acute:chronic ratio is calculated by taking the current weeks training load (acute load) and dividing it by the average load of the four weeks preceding (chronic load). A low ratio < 1.35 indicates that the new workload is not dissimilar to previous workloads, whereas a high ratio represents a substantial jump in load. They suggest using this method with external load measures using GPS or accelerometers but it has also been used with internal measures of load such as sRPE (Drew & Purdam, 2016). Using the acute:chronic ratio, injury risk can be described as a function of load and the acute:ratio can be used to predict injury and assess injury risk (Hulin et al., 2015).

For example, in cricket if the acute workload was twice that of the chronic the injury risk for fast bowlers increased by a factor of three (Hulin et al., 2014). Importantly, a

**Figure 4.** The workload injury aetiology model of Windt and Gabbett (2017). The application of workload is the exposure to risk. Workload is essential to provoke training adaptations but too much results in fatigue or injury. Fatigue or injury might predispose the athlete to further injury.
high chronic workload was demonstrated to be protective in this case. A high chronic workload was also found to be protective in rugby in most cases unless there was a substantial increase in acute workload (Hulin et al., 2015). In another study, training loads that exceeded 10% of the week prior substantially increased the injury risk (Gabbett, 2016). There appears to be a ‘sweet spot’ (acute:chronic ratios 0.85 -1.35) within training workloads where injury risk is low but performance adaptation can still occur (Gabbett, Hulin, et al., 2016). In this model, overuse injuries (the most common injury type in dance) are considered to be preventable as they can be reconceived of as “errors in training load” (Drew & Purdam, 2016; Jacobs et al., 2012), or in other words, overuse injuries are directly related to load (Gabbett, 2016). In a recent study which applied this model to male professional football (soccer) players they found overuse injuries to be increased with a high acute:chronic ratio with moderate chronic workloads of high-speed running (Jaspers et al., 2017). A moderate acute:chronic ratio was observed to be protective with loads determined by accelerometer. Gabbett (2010) was able to demonstrate that non-contact soft tissue injuries which include overuse injuries could be predicted using workload data. The ability to predict the likelihood of injury for different workloads in dance would be invaluable in addressing the problem of overuse injuries in dance.

2.5 Quantifying training load in dance
Jeffries et al. (2017) is currently the only study that has quantified training load in the context of dance using sRPE. Jeffries compared sRPE with heart rate (HR) derived methods and accelerometers in order to assess its validity for use. This study examined the total workloads undertaken by 16 pre-professional dance students training in contemporary and ballet dance, including rehearsals for performance, over a seven-week period. They concluded that the average weekly workloads of dancers were much higher than those documented in professional Australian football players. Jeffries et al recorded the changing weekly workloads and while they do not directly refer to it, there appears to be a large training load spike at week 3 representing a 33% or greater jump in workload from the preceding weeks. Using their data it is possible to estimate an acute:chronic ratio of greater than or equal to 1.5, which represents a moderate to high ratio, placing that weeks’ training in the “danger zone” where injury risk is high (Gabbett, 2016). Jeffries’ et al study was not an investigation of injury, however it does indicate that capturing workloads was possible using sRPE, at least in
the context of research. At least in principle, with careful monitoring by dance
teachers such significant fluctuations could be avoided. Quantifying training load can
therefore be seen as a potentially important method of assessing injury risk and can
contribute to the formation of preventive strategies such as the adjustment of
workloads. Training load is an important consideration for performance optimisation
and, more importantly, is now understood to be a key variable in injury aetiology
(Windt & Gabbett, 2017).

2.6 Summary
The ability to quantify training load conveniently would provide dance with a tool to
monitor and optimise dance performance. Based on observations in sporting contexts,
it appears likely that injuries, particularly overuse injuries, might be reduced if
workload is managed to avoid training spikes. In dance, both internal and external
training loads could be used to calculate acute:chronic ratios and relate them to injury.
Load thresholds in terms of over and undertraining could be established for dance and
its various genres. Before such application, it is necessary to consider the various
practical methods of quantifying internal and external loads.

3.1 Quantifying intensity and training load – Subjective measures

3.1.1 The Category Ratio method for measuring intensity
Borg developed the Category Ratio (CR) method for quantifying the subjective
experience of intensity in exercise (Borg, 2007). He proposed that intensity in a
training session could be measured using a scale that is reflective of the different
sensations experienced by the athlete and which are associated with different levels of
effort. The most widely used method is the CR-10 (Haddad et al., 2017). However
later it was suggested that a new scale, the CR-100, could be used for a greater degree
of sensitivity (Borg & Borg, 2002). Scott, Black, Quinn, and Coutts (2013) found the
CR-100 was no more sensitive than the CR-10 and are therefore equivalent and
interchangeable. More recently, Fanchini et al. (2016) found the CR-100 scale was
more accurate at capturing the athletes experience due to its wider range and finer
gradations.
3.1.2 The session rating of perceived exertion to calculate training load

One of the most convenient methods for quantifying internal training load is the session rating of perceived exertion (sRPE). This method was developed by Foster (Foster et al., 1995). The rating of perceived exertion had been used previously to monitor intensity during an exercise session (Foster et al., 2001). The advantage of the sRPE is that it is non-invasive, requires no equipment or technical expertise, and is simple to administer (Haddad, Chaouachi, Castagna, Wong del, & Chamari, 2012; Haddad, Padulo, & Chamari, 2014; McLaren et al., 2017). To calculate sRPE, an athlete indicates how intense they found their training using the Borg scale of rating intensity (either CR-10 or CR-100) and this scoring is multiplied by the duration of time (minutes) spent training to calculate training load (Foster, 1998). Foster validated this method against other objective methods for calculating internal training load such as the Banister’s TRIMP (Foster et al., 1995), and the summated heart rate zones method of Edwards for swimming, plyometrics, weight training, cycling, speed skating (Foster, 1998; Foster et al., 2001). In a recent review, 34 studies were identified validating this method for a wide variety of sports (Haddad et al., 2017). At the proposal stage of the study reported in this thesis, the use of sRPE had not been investigated in dance, however, the findings of a recent paper provides preliminary evidence in support of the validity of this method for use in contemporary dance (Jeffries et al., 2017).

3.1.3 Limitations of RPE and sRPE

Perception of effort is also influenced by factors that are independent of the external load undertaken (Haddad et al., 2013). Jeffries et al. (2017) found that sleep quality, motivation, and muscle pain all contributed to sRPE. Psychological states such as anxiety or depression can also influence sRPE (Impellizzeri, Rampinini, & Marcora, 2005). The degree of experience and competency were demonstrated to influence sRPE in both competitive swimmers (Barroso, Cardoso, Carmo, & Tricoli, 2014), and in soccer (Brink, Frencken, Jordet, & Lemmink, 2014). The ability to rate exertion appears to be a function of cognitive development which, in turn, is a function of age, and the accuracy of RPE improves with age from childhood into adolescence, and then stabilises in adulthood (Groslambert & Mahon, 2006). An increased frequency of training appears also to improve RPE accuracy (Gearhart, Becque, Hutchins, & Palm,
2004). Fatigue and genetics are also factors known to influence sRPE (Scott, Lockie, Knight, Clark, & De Jonge, 2013). These non-load measures reduce the correlation between sRPE and other measures of load (McLaren et al., 2018). The session RPE can be conceptualised as a multi-factorial construct comprised of load and non-load information.

3.1.4 Perceived exertion has distinct dimensions
Tenenbaum et al. (1999) proposed separating the perception of exertion into three distinct dimensions, these are: sensory-discriminative, cognitive-evaluative, and motivational affective. Interestingly, these dimensions are the same as those involved in the perception of pain as proposed by Melzack and Wall (1965). The Sensory-discriminative dimension represent sensations related to the physiological processes employed in physical effort. These sensations can arise from exertion felt peripherally in the muscles and limbs, and centrally in the chest from the cardio-pulmonary system, and can be differentiated by people even as they occur concurrently (Demura & Nagasawa, 2003). The cognitive-evaluative dimension is the subjective self-assessment of the sensations of effort and is therefore an interpretation process for the different physiological inputs. The primary purpose of this dimension is to avert overexertion and injury. The motivational-affective dimension is the emotional and motivational response and associations towards the experience of exertion and relates to concentration, determination and a person’s self-efficacy. These individual dimensions can also be discretely perceived and differentiated (Hutchinson & Tenenbaum, 2006). Whilst it is important to understand how these non-load factors, such as those arising from the motivational-affective dimension, contribute to sRPE they may be comparatively small (Haddad et al., 2013). Alternatively, they may fluctuate in their influence and importance, however, this is a subject of further research (Haddad et al., 2017).

In considering changes in external load it is the sensory-discriminative dimension that most reflects this input. The intensity of sensation experience in the periphery, and centrally, increases with increasing external load. The cognitive-evaluative dimension, as it is the process of assessing these inputs, will likewise increase. However, this does not necessitate that these two dimensions have identical responses, as the cognitive-evaluative dimension is a person’s self-assessment of
multiple sensation inputs and is reflected in the RPE score (Hutchinson & Tenenbaum, 2006). The motivational-affective dimension can be measured using questionnaires which assess attributes such as determination and self-efficacy (Tenenbaum et al., 1999). These attributes are likely to affect the cognitive-evaluative dimension, as they influence the evaluation of threat posed by physical exertion. However, the degree these influence sRPE requires further investigation (Haddad et al., 2017; Hutchinson & Tenenbaum, 2006). Since it is possible to discern different dimensions of effort the use of a ‘gestalt’ or global score such as sRPE has at various times been questioned (Pandolf, Billings, Drolet, Pimental, & Sawka, 1984; McLaren et al., 2018). The rating of perceived exertion has been shown to be influenced by the most dominant sensation and may not necessarily reflect all of the contributing influences (McLaren et al., 2017). Exertion sensation arising in the periphery is perceived more intensely and may dominate those arising centrally (Demura & Nagasawa, 2003). Thus, local loading processes may influence sRPE more. From the perspective of load, it is possible to separate ratings of exertion for central and peripheral components of the sensory-discriminatory dimension. This would provide information about the proportionality of these different inputs.

Recently, the division between central and peripherally perceived sensation has been shown to correspond to specific load pathways (Vanrenterghem et al., 2017). Biomechanical load is most reflected in peripherally perceived exertion, whereas aerobic load is reflected in centrally perceived exertion. Taking separate ratings for centrally and peripherally perceived exertion would provide more detailed information about the biomechanical or cardiorespiratory components of internal load. This would be very useful as the time required to adapt from biomechanical stimulus is slower than cardio-respiratory adaptations (Vanrenterghem et al., 2017). Therefore, a rating that is high in the periphery and lower centrally might mean a greater rest period is required or a training modality that does not biomechanically load the body such as cycling (Vanrenterghem et al., 2017). The separation of RPE and sRPE into component parts provides more detailed information and these components have been referred to as differentials of the rating of perceived exertion (dRPE).
3.1.5 Differential RPE
Differential ratings of perceived exertion are not a new idea but have only recently been used in training load monitoring (Pandolf et al., 1984; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015) Differential ratings for peripheral and centrally mediated effort have been used in Australian football (Weston et al., 2015), football (soccer) (Gil-Rey, Lezaun, & Los Arcos, 2015) cycling and treadmill running (McLaren et al., 2016) and rugby (McLaren et al., 2017). The number of differentials used in these studies has been variable with several studies focussing on chest sensation or breathing sensation and legs (Gil-Rey et al., 2015; McLaren et al., 2016). Weston et al. (2015) used these in their rugby study, and added a differential for how technical an athlete’s session was to reflect the cognitive load of play. Cognitive load was shown to be independent of physical demand as it was rated highly but did not correlate with physical load measures (Weston et al., 2015). The most recent studies investigated dRPE have used these differentials but have added upper peripheral exertion of the arms. Depending on the activity being undertaken the contribution of each of these differential ratings to overall sRPE will change (Weston et al., 2015). Differential ratings for legs aside from biomechanical stress may also reflect lactic acid accumulation (and other muscle metabolites) associated with anaerobic energy production (Boyd et al., 2011). Borg, Hassmen, and Lagerstrom (1987) demonstrated that the anaerobic energy system when utilised will affect the ratings of perceived exertion and therefore sRPE. Therefore, differential ratings in the periphery may include anaerobic contributions as well as biomechanical ones. Differentials for chest or breathlessness indicate primarily cardiovascular demand (Vanrenterghem et al., 2017). If dancers consistently report high values for centrally perceived exertion this could indicate that more aerobic training is necessary. Likewise, if differential ratings for legs are consistently high then dance training might require more focus on leg strength, minimisation of biomechanical stress and muscle endurance.

3.1.6 Latency effects
Because sRPE is a subjective evaluation for an entire session it is important that the most recent experience within a session does not unduly influence the scoring. This biasing is known as a latency effect. To avoid this, Foster suggests that sRPE should be recorded 30 minutes after a training session with the assumption that at least in
theory this period of time is sufficient for its effect to be minimised (Herman, Foster, Maher, Mikat, & Porcari, 2006). However, it is clear that not scoring the sRPE until 30 minutes post exercise greatly reduces the practicality of this method, particularly outside of professional sport. Recently, the latency effect has been examined and there is a disagreement as to whether or not it is a problem, and also what amount of time if any, is sufficient to avoid it (Arcos, Martínez-Santos, Yanci, Mendiguchia, & Méndez-Villanueva, 2015; Fanchini, Ghielmetti, Coutts, Schena, & Impellizzieri, 2015; McLaren et al., 2016). Jeffries et al. (2017) cite the study by Uchida et al. (2014) on boxing that concluded there is no difference in latency between 10 minutes and 30 minutes post session. On the basis of this finding, they collected sRPE within a 10 minute period following a dance session. However, given that this matter is not settled and more research is required it seems advisable, as McLaren et al. (2016) suggest, to adhere to the 30 minute rule if feasible. In the contemporary dance context this may not be possible, as breaks between classes tend to be shorter in duration.

3.2 Quantifying intensity and training load – Objective measures

3.2.1 Dance studies quantifying intensity
There are a number of technical methods that can be used to quantify training load which are based on oxygen consumption, heart rate, and lactate (Scott, Duthie, Thornton, & Dascombe, 2016). Wyon et al. (2002) examined the changing oxygen consumption and heart rate responses in contemporary dance students, graduates, and professionals within a class setting using heart rate monitors and telemetric gas analysers. They do not, however, quantify the total energy expenditure but rather the energy expended per minute of activity which reflects the changing intensity of class. Wyon et al. (2002) conclude that contemporary dance class is predominantly moderate in intensity but with a final phase that is of a higher intensity sufficient enough to result in aerobic training adaptations. In another study, Wyon et al. (2004) used a similar approach to investigate the different phases of training that contemporary dancers undertake, class, rehearsal, and performance. They were able to demonstrate that the intensity profiles of dance class rehearsal do not reflect those of performance. A recent paper confirmed this finding in a study of postgraduate and undergraduate dance students (Beck, Wyon, & Redding, 2018). Thus, the transition from class and rehearsal to performance represents a change in workload.
Wyon et al. (2015) recognise that there are other factors contributing to the physical demands of dance class that they have not assessed using the above methods which are primarily measures of the cardiovascular system. They suggest the use of lactate thresholds because dance utilises both anaerobic and aerobic energy systems. Beck et al. (2018) have recently investigated lactate thresholds by measuring lactate in the blood and found that in a year of dance training this value did not change, suggesting that aerobic fitness likewise did not change. Aerobic fitness reduces the involvement of the anaerobic system and thereby reduces fatigue because it does not deplete the energy stores of the muscle, or change the pH as occurs with the anaerobic system (Impellizzeri et al., 2006). This is because aerobic fitness raises the threshold at which lactate begins to accumulate. Professional dancers have been shown to have higher levels of cardiorespiratory fitness than students and therefore do not use the anaerobic energy system to the same extent as students (Needham-Beck, 2017).

3.2.2 The difficulty of quantifying aspects of dance

Jumps or movements that quickly change level, which are found in dance are more anaerobically taxing (Beam & Wiersma, 2012). Jumps have been documented to result in forces passing through the lower limb ~12 times greater than body weight and therefore also represent a high degree of biomechanical stress (M. Liederbach et al., 2008). There is no easy way to quantify this stress, however, recently some blood markers have been proposed such as serum creatine kinase (Vanrenterghem et al., 2017). However, taking blood markers is invasive, complicated and therefore inconvenient for on-going regular monitoring (Lambert & Borresen, 2010). Monitoring oxygen consumption requires elaborate equipment which is also invasive and observed to affect the dancers movement (Wyon et al., 2004). Whereas, the use of heart rate monitoring is less invasive and relatively easy to apply in the field (Buchheit, 2014).
3.2.3 Using heart rate to measure intensity
Percentage heart rate peak (\%HR_{peak}) is an objective measure of training intensity, which takes the highest heart rate achieved by an individual in a session as a percentage of that same individual’s maximum heart rate (Haddad et al., 2017; Herman et al., 2006; Scott et al., 2013). By definition, maximum heart rate cannot be exceeded. According to Herman et al. (2006) because \%HR_{peak} is an accepted method for capturing training intensity, it can be used to validate subjective measures of intensity. Jeffries et al. (2017) have also used \%HR_{peak} in this way in dance as have Scott et al. (2013) with rugby. In order to calculate a value for \%HR_{peak} the maximum heart rate must be known.

3.2.4 Maximum heart rate tests
Heart rate responses will be different depending on the physical task and are therefore task specific (Achten & Jeukendrup, 2003). A fitness test which elicits a heart rate maximum should also be specific to the sport or dance genre for which it is to be applied (Krstrup et al., 2003; Wyon et al., 2003). This is because an athlete or dancer will have made physiological and biomechanical adaptations specific to their discipline which will allow them to perform at a higher intensity than with other more foreign testing protocols (Davies, Daggett, Jakeman, & Mulhall, 1984; Scheer, Ramme, Reinsberger, & Heitkamp, 2018).

There are a number of different maximal tests which elicit a maximum heart rate and these most commonly require running or cycling (Longo, Aquilino, Cardey, & Lentini, 2017). The Yo-Yo endurance test is commonly used in team sports (eg rugby, hockey, netball etc) and because of its biomechanical profile is appropriate for sports that require running, fast changes of direction and which stop and start (Longo et al., 2017). The Yo-Yo test was recently modified in order to create a version more specific to intermittent sports called the Yo-Yo intermittent recovery test (Bangsbo, Laia, & Krstrup, 2008). Jeffries et al. (2017) used this test in their dance study. The appropriateness of this test for dance is questionable as the specific movement profiles of dance do not resemble those of running and cycling. Furthermore, the specific biomechanical adaptations seen in dancers can make them ill-suited to such tests and risks injury (Redding et al., 2009; Wyon et al., 2003).
3.2.5 Dance specific fitness testing
This problem led Wyon et al. (2003) to develop a number of dance specific fitness tests for ballet and contemporary dance. The tests are incremental in nature, with increasing levels of intensity and have varied movements appropriate to each genre of dance being tested. For instance, the contemporary dance includes full body movement that is fluid and varied, with deep lunges and later in the test jumps with both legs and single legs. These tests were not specifically designed to obtain a heart rate maximum but are likely to do so in most instances (Wyon 2018, personal communication). Perrotta, Held, and Warburton (2017) note that when testing in the field, an athlete’s heart rate may be higher than that found in maximum testing in which case the higher heart rate value will be considered the maximum.

3.2.6 Calculating internal training load using heart rate
Heart rate is considered to be one of the more important physiological measures for quantifying internal training load (Haddad et al., 2017; Scherr et al., 2013). There are a number of different methods for deriving internal load from heart rate measurements. The most commonly used in relation to sRPE have been Banister’s and Edward’s TRIMP (Haddad et al., 2017). These methods quantify internal training load into a single interpretable value.

3.2.7 Banister’s TRIMP
The term TRIMP is an abbreviation for “training impulse” a phrase coined by Banister in 1980 (Banister & Calvert, 1980) and is conceptually equivalent to internal training load. This method, like the sRPE method, requires measurements of both duration and intensity to calculate the load. A weighting factor ($\gamma$) is added to the calculation in order to equate short bursts of high-intensity with longer durations at lower intensity. This factor is based on male or female lactic acid response to training intensity and is therefore physiologically derived. Wyon and Redding (2005) have advocated the use of this method for quantifying internal training load in dance. One criticism of this approach is that it is based on a generalised lactic acid response for each sex (Akubat, Patel, Barrett, & Abt, 2012). Whilst it is possible to generate an individualised TRIMP (iTRIMP) based on a specific individual’s lactic acid response this requires technical and medical expertise as well as financial resources to
implement (Manzi, Iellamo, Impellizzeri, D'Ottavio, & Castagna, 2009), and may therefore not be optimal for practical implementation in the field.

The calculation for the Banister’s TRIMP is as follows (Banister & Calvert, 1980):

\[ \text{Training impulse (arbitrary units) = duration of exercise (ΔHR)y} \]

Where:

\[ y = 0.64e^{1.92\Delta HR} \text{ (Male)} \]
\[ y = 0.86e^{1.67\Delta HR} \text{ (Female)} \]

\[ \Delta HR = (HR_{exercise} - HR_{rest})/(HR_{max} - HR_{rest}) \]
\[ e = 2.712 \]

3.2.8 Criticisms of Banister’s TRIMP

Several commentators have criticised Banister’s TRIMP for application in intermittent sports because the calculation requires taking an average (Wallace et al. (2014), Borresen and Lambert (2008) and Akubat et al. (2012)). It is clear that using heart rate averages over a whole session is not a valid method for ascertaining the intensity of an intermittent training session. This is because the average heart rate of a session does not necessarily capture the full breadth of changes in intensity within a session (Needham-Beck, 2017). Redding and Wyon (2003) likewise argue that calculating the average workload for a training session for intermittent activity will not produce any meaningful information.

Calculating an average HR over a whole session may under or over-estimate the session intensity, and therefore impact on the accuracy of workload. While the criticism of using mean data from intermittent training is legitimate in this case, there does appear to be a widespread misreading of what was originally proposed by Banister. Banister writes about this in his seminal chapter “Modelling Elite Athletic Performance” (MacDougall, Wenger, Green, & Canadian Association of Sports, 1991). He provides examples of a training session with three intervals of high-intensity (p 409, (MacDougall et al., 1991)) and does use mean heart rate, but these are means of the peak intensities of the three intervals. This is done for the convenience of estimation as the intensity levels of these peaks were of a comparable
level. This is not equivalent to averaging the heart rate for all values across the entire training session. He suggests adding the intervals together to calculate the training load for the whole session or in other words the load of each interval at a certain intensity is calculated separately and then summed to produce a total for the entire session. This point is clearly stated in their paper (Morton, Fitz-Clarke, & Banister, 1990) from which the following figure is taken (see figure 5).

![Proposed method for obtaining HR values for Banister TRIMP](image)

**Figure 5.** Proposed method for obtaining HR values for Banister TRIMP. The graph represents heart rate over time. There are peaks of intensity each of which can be scored and the sum of all the segments will be the TRIMP (Morton et al., 1990).

If heart rate is reasonably steady for an entire session only then may an average for the entire session be appropriate (Morton et al., 1990). Jeffries et al. (2017) appear to have used averages within the Bannister TRIMP calculation, as they report using the average change in heart rate ratio. Many studies report using mean heart rate data with Banister’s calculation in relation to intermittent sports such as soccer (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004) (Alexiou & Coutts, 2008) (Wrigley, Drust, Stratton, Scott, & Gregson, 2012), taekwondo (Haddad et al., 2011; Haddad et al., 2012) interval training on a cycle (Wallace et al., 2014), karate (Padulo et al., 2014), and fencing (Turner et al., 2017). Not all studies examining intermittent sports and using Banister’s TRIMP report clearly how they have used the calculation as they do not specify how they have calculated the variable of heart rate for the exercise such as with basketball (Manzi et al., 2010), rugby (Lovell et al., 2013)
(Akubat et al., 2012), and Canadian football (Clarke, Farthing, Norris, Arnold, & Lanovaz, 2013). It may well be that these studies have not used mean heart rate data in the calculation.

To avoid the problem, of calculating an appropriate average HR it is possible to apply Bannister’s TRIMP calculation to every heart rate value captured in a training session with the duration being the sampling rate of the HR monitor (typically 1 sec intervals) Subsequently, the TRIMP is then calculated as the sum of values. This is admittedly more complicated and for ease of practical application requires proprietary software or customised spreadsheet, but it does eliminate the invalid use of mean data and provides a more accurate measure of training load as envisaged by Banister.

3.2.9 Edwards’ TRIMP
The Edwards’ TRIMP is based on the time an individual spends within five different zones of intensity. The zones are expressed as percentages of that person’s heart rate maximum. The first zone is 50-60%, the second is 60-70%, the third 70-80%, the fourth 80-90% and the fifth 90-100%. Each zone is given a weighting factor and the more intense the zone, the greater the weighting factor (Edwards, 1993). This weighting ensures that the same duration at a higher intensity will have a greater impact than at a lower intensity in the calculation. However, both the zones and the weighting factors are arbitrary and are not connected to any physiological response to training (Akubat et al., 2012). This method appears to have been derived theoretically and not via experimentation (Haddad et al., 2011). Nevertheless, this method has been widely used to calculate internal training load in rugby (Aughey, Elias, Esmaeili, Lazarus, & Stewart, 2016), Canadian football (Clarke et al., 2013), various training modes such running interval training on cardio machines (Borresen & Lambert, 2008), basketball (Manzi et al., 2010), taekwondo (Haddad et al., 2011), team gymnastics (Minganti, Capranica, Meeusen, Amici, & Piacentini, 2010), swimming (Wallace, Slattery, & Coutts, 2009) and diving (Wallace et al., 2009). Furthermore, Edwards’ TRIMP has been validated against Bannister’s TRIMP training load (Borresen & Lambert, 2008; Haddad et al., 2012), however, in both of these studies Bannister’s TRIMP may have been incorrectly calculated using the average HR across the session rather than summing individual HR values.
3.2.10 The problem of using heart rate with intermittent or high-intensity training

Heart rate may not always be appropriate for determining internal training load. Jeffries et al. (2017) note that HR based methods for validating internal training load against sRPE yielded much lower correlations for ballet than for contemporary dance. They suggest that this may be because ballet class typically include longer rest periods within a class structure and also tends to utilise the anaerobic energy systems due to the greater number of jumps used within ballet (Liederbach et al., 2006). Using HR as a measure of intensity for exercise is based on the relationship between HR and oxygen consumption which reflect the energy demand on the aerobic system (Achten & Jeukendrup, 2003). This in turn is based on the linear relationship between oxygen consumption and submaximal exercise. However, at higher intensities this relationship is not linear making it difficult to extrapolate energy demand from HR. Foster et al., (2001) argue that heart rate is not appropriate for calculating load with high-intensity intermittent training such as weight training, plyometric or intense bouts of interval training. This is because these types of training are not dependant on aerobic metabolism for energy. Thus, it can be argued that heart rate derived measures of load are reflective of the aerobic or cardiovascular load which in some circumstances may not be the main component of activity being undertaken and will therefore not provide a useful indication of total load. Foster suggests sRPE is better suited to evaluating these forms, but of course this requires a validation process against other internal load measures such as those that might represent biomechanical load or anaerobic metabolism (Foster et al., 2001; McLaren et al., 2018; Vanrenterghem et al., 2017).

A decoupling between sRPE and heart rate measures as noted with ballet has also been observed in other studies. In taekwondo, Edwards’ and Banister’s TRIMP had lower correlations with sRPE ($r=0.31$ Edwards, $r=0.32$ Banister) when the training was intermittent, plyometric or at high velocity. Lovell et al. (2013) found skill-based training had moderate correlations with Banister ($r=0.45$) compared with conditioning sessions where correlations were higher (in the range $r=0.68$ to 0.75).

Despite these weaknesses HR based methods have still been used extensively and have concluded that sRPE is a valid measure of training intensity, in a large number
of intermittent sports with most correlations reported between $r=0.45 – 0.97$ (Alexiou & Coutts, 2008; Clarke et al., 2013; Impellizzeri et al., 2004; Lovell et al., 2013; Manzi et al., 2010; Minganti et al., 2011; Padulo et al., 2014; Scott et al., 2013).

### 3.3 Statistical methods for correlating sRPE with other measures

Comparison between studies correlating sRPE with other measures of load (both external and internal) have been limited by differences in statistical methods used for analysis (McLaren et al., 2018). Some studies have pooled their data to determine group correlation values (Gomez-Piriz, Jiménez-Reyes, & Ruiz-Ruiz, 2011; Scott et al., 2013) However, this method falsely assumes that each session measurement for the same individual across all their sessions are independent. The alternative method uses within-individual correlations expressed as a mean and then compared to the entire sample. This method has been used in Australian football (Scott et al., 2013), rugby (Lovell et al., 2013) and football (soccer) (Kelly, Strudwick, Atkinson, Drust, & Gregson, 2016) and in dance (Jeffries et al., 2017).

### 3.4 Conclusion

Injury is a problem for all genres of dance. Overuse injuries are the most prevalent in dance, however, these injuries are considered to be preventable if training loads are managed effectively. A so-called ‘sweet spot’ between training adaptation/optimisation and lower injury risk can be defined within different thresholds of training load. However, in order to apply this approach, appropriate measures of training load must be developed in dance. Internal training load in dance could potentially be determined using sRPE and dRPE. These are convenient measures which have been effectively used in many sports to monitor internal training load. The relationship between sRPE and dRPE and other measures of workload is important to describe if they are to be used for monitoring training load in dance. While sRPE may be valid for use in pre-professional contemporary dancers it has not been investigated at the professional level or across different companies at varying levels of experience. To date, dRPE has not been investigated, nor has its relationship to sRPE been investigated, yet this might provide a more detailed account of dancers’ perceptions of exertion. Internal load is the result of multiple influences and it is unlikely there is a single objective measure with which to quantify it. Likewise, the perception of exertion is influenced by multiple factors. Consequently, it is
appropriate to investigate how different aspects of perception relate to different objective measures of internal training load. Therefore, an investigation into the relationship between sRPE and dPRE with HR derived measures of training load is warranted. A study of the relationship between the session and differential ratings of perceived exertion, and heart rate derived measures of internal load across different contemporary dance companies with different levels of experience follows in Section II of this thesis.
References


Note: This manuscript is formatted according to the Guidelines for Authors for the *Journal of Dance Medicine and Science* available here: [https://goo.gl/PUDQqs](https://goo.gl/PUDQqs). References to the thesis Appendices are indicated in square brackets eg [see thesis Appendix A].
The relationship between differential and session ratings of perceived exertion with heart-rate derived measures of internal load in contemporary dance: An observational study

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Abstract

Background: The injury burden in dance is substantial and overuse injuries predominate. Training load is an important variable in understanding overuse injury aetiology and in the formulation of injury prevention strategies.

Aim: To investigate the application of differential (dRPE) and session ratings of perceived exertion (sRPE) in contemporary dance and to explore their relationship with objective measures of internal training load derived from heart rate in contemporary dancers.

Design: Cross sectional observational design using field-based data collection.

Methods: Using the centiMax ratings of perceived exertion, a convenience sample of 31 dancers were recruited from three companies (26 females, 5 males; [mean±SD] age = 21±2.6 yr, mean body weight 65.1±10.5 kg; total duration weekly dancing 28.3±7.9 h, mean session duration 28.3±7.9 mins, total weekly duration 28.3±7.9 h/week) and provided sRPE for dance classes and differential ratings for breathlessness (RPE-B), technical difficulty (RPE-T), arm exertion (RPE-A) and leg exertion (RPE-L) from 174 individual sessions. These RPE values were multiplied by session duration to calculate session training load, (sRPE-TL) and differential load values, (dRPE-T, dRPE-B, dRPE-A, and dRPE-L). Bannister’s and Edwards’ training impulse (TRIMP) were calculated from heart-rate recordings for all sessions. Data were analysed using magnitude based inferences.

Results: Within-individual correlations between Bannister’s or Edwards’ TRIMP and differentials were respectively: sRPE-TL (r=0.38, r=0.41), dRPE-B (r=0.47, r=0.49), dRPE-A (r=0.39, r=0.41), dRPE-T (r=0.22, r=0.29) and dRPE-L (r=0.29, r=0.27). The strongest correlations were between dRPE-B and Bannister’s or Edwards’ TRIMP. Multiple linear regression revealed that a substantial proportion of variance (78%) in sRPE can be explained by RPE-L and RPE-B.

Conclusions: This study provides further evidence that dRPE represent different sensory input and different dimensions of effort such as those that arise centrally (RPE-B), those that arise peripherally (RPE-L, RPE-A) and those that are cognitive (RPE-T). The current findings demonstrate that dRPE-B is more indicative of the cardiovascular load pathway than sRPE-TL in contemporary dancers. For applied practitioners, dRPE-B provides a simple means to quantify and monitor cardiovascular load in dancers for use in their training management and in future injury prevention studies.

Keywords: dancing, injuries, monitoring training, training impulse, physical exertion
Introduction

Dance has always been a part of human history and movement culture (1). However, it is only recently that dancers have been considered athletes at risk of injury because of the large amount of training required to achieve artistic and technical mastery (2, 3). The injury burden in dance is substantial (2, 4), with overuse injury being the most common type (5-7). Recently, a new injury aetiology model has been advanced that explicitly considers workload as an injury risk factor (8). Overuse injuries are considered to be preventable because they are errors in the application of workload which can be corrected (8, 9). Convenient, reliable and valid methods for monitoring workload in the field are therefore of importance for successful injury prevention initiatives (10). The ability to quantify workload has enabled researchers to observe how shifts in workload affect injury risk and predict when injuries are likely to occur (11, 12). Furthermore, workload quantification in several sports suggests a ‘safe zone’ of workload where certain workloads result in adaptations that are protective against injury (13, 14). The rate and degree of workload changes have been shown to influence the probability of injury with sudden and large increases being particularly problematic (15). Workload can be divided into external and internal components (16). External workload is the observable work performed by the athlete but which is independent of their individual characteristics or status (17), whereas internal workload is an athlete’s individual physiological (biomechanical and biochemical) response to the external workload performed (10). One method for quantifying internal workload that has attracted a great deal of interest in sport science is the session rating of perceived exertion (sRPE) (16). This method is non-invasive, requires no equipment or technical expertise, and is inexpensive (18). With the arrival of micro technologies, objective information for quantifying workload in the field is increasingly common in sports (19). Heart rate monitors are widely used to quantify internal load (20), while for external workload, accelerometry and global positioning systems are increasingly common (19). Session RPE has been shown to correlate sufficiently with objective measures to be considered valid in many sports, including rugby (19) football (soccer) (21), gymnastics (22), karate (23), and diving (23). Despite this utility, only one previous study has investigated sRPE in dance (24). Session RPE is influenced by factors independent of external workload such as sleep (24), motivation (24), age (25), experience (26), training status, fatigue and genetics (27). This wide range of determinants explains why near perfect correlations between sRPE and other measures of training load are unlikely (10). Session RPE can be considered a global measure which is multifactorial in nature and includes, but is
not limited to, load information. Similarly, objectively observable internal load can be understood as a multifactorial construct with different contributing mechanisms and therefore cannot be captured by a single method of measurement (16). Heart rate derived measures of internal load have been used to validate sRPE in many intermittent and high-intensity sports but can only be an indication of the aerobic load as they do not adequately account for anaerobic or biomechanical load contributions (28-30). Dance is considered intermittent and utilises both anaerobic and aerobic energy pathways (31). Currently, convenient field-based measurements of biomechanical stress and anaerobic load are still in development (29, 32).

As no single objective measure exists for internal load it may be inappropriate to use sRPE as a single subjective measure as it cannot provide information about the different load pathways experienced (16, 33). Differential RPE (dRPE), which uses separate ratings for technical/cognitive demand (RPE-T), degree of breathlessness (RPE-B), and the intensity of arms (RPE-A), or leg work (RPE-L), are more sensitive measures than sRPE and are intended to distinguish between these dimensions of effort as each is perceived differently (29, 34). Aerobic load is centrally driven and equates with the differential rating for breathlessness, whereas anaerobic and biomechanical effects are experienced more peripherally and are reflected in the differential ratings of the legs or arms (30). Thus, dRPE could be used to provide information about the extent to which the different pathways in dance are being challenged. The degree with which HR derived internal load is associated with each differential is likely to be different and merits investigation. Differentials of RPE have not yet been studied in dance. Likewise, sRPE has yet to be investigated across different companies of dancers including professional dancers. This is important as the stability and generalizability of sRPE and dRPE needs to be established, prior to their consideration as measures of load in dance injury prevention research. Therefore, the aim of this study was to investigate sRPE and differential sRPE and their relationship to objective HR derived measures of internal load, across several companies of dancers with different levels of experience.

Methods

Design and ethics

This was an observational cross-sectional design with all data collection undertaken in the field during normally scheduled group dance sessions. Prior to data collection a preliminary session was held to explain the study and its associated risks to potential participants. An
information sheet and consent form outlining the study procedures were provided to all participants. All participants provided written informed consent. Consent was also sought for the video recording of all data collection sessions (these data are not reported here). The study was approved by the Unitec Research Ethics Committee (UREC 2016-1073) [see thesis Appendix A].

**Participant recruitment**
Convenience samples were obtained from three different dance institutions, one professional dance company and two tertiary institutions offering undergraduate qualifications. Of the two tertiary institutions, the first was a full-time programme, and provided two cohorts one at Year 2 level, and the other at Year 1 level. The second tertiary institution was a university with part-time technique training and provided one cohort at Year 3 level.

**Inclusion criteria**
Participants were eligible for study enrolment if they were of professional level (as defined by dance being their primary vocation), or enrolled in an undergraduate tertiary dance programme. All participants were required to be practicing in contemporary dance.

**Exclusion criteria**
Participants were excluded if they were physically incapable of participating fully in class (e.g due to illness or injury). All participants were required to satisfy a physical activity readiness screening questionnaire, the PAR-Q (35).

A second session was undertaken to gather biometric data (height, body weight, and dance background) and to familiarise participants with the Borg CR-100 centiMax scale (36), and the use of heart rate monitors [see thesis Appendix B]. The Borg CR-100 was selected because it is a more sensitive measure than the more commonly used CR-10 (37). A dance specific fitness test (DAFT) was used to obtain a maximum heart rate (HR) for each participant (38). The usual maximum HR tests employing running or cycling were deemed inappropriate as neither reflect the specific biomechanical demands of dance and are potentially injurious due to their unfamiliarity (38, 39). The dance specific test also provided an opportunity for participants to connect different levels of physical intensity with associated physical sensations as indicated on the CR-100, including that of a maximum effort. Explanations for the differential session ratings for cognitive/technical demands (RPE-
T), breathlessness (RPE-B), leg muscle exertion (RPE-L), and upper-limb muscle exertion (RPE-A) were likewise explained. Participants took their assigned HR monitor home to record resting HR on morning waking for >3 minutes on three successive days prior to class data collection. All institutions routinely scheduled two or three contemporary dance classes per week. Data collection took place at successive classes of contemporary dance at each dance institution across 2-3 weeks. Polar heart rate monitors were used for all HR recording (models FT-80; RS800cx; RS400, RCX5, H7; Polar, Kempele, Finland). Heart rate was recorded at a sampling rate of 1Hz. Fifteen minutes following the conclusion of each class the sRPE and the differential questionnaires were administered.

Quantifying training loads
Heart rate data was downloaded from each HR monitor using proprietary software (Polar Electro Oy, Kempele, Finland), before export to training analysis software (iSMARTtrain, v4.1, Yellow Field Technologies, Scotland) in order to calculate internal training load using Edward’s (40) and Banister’s TRIMP (41, 42). Edwards’ TRIMP and Banister’s TRIMP are the most common HR-based methods for calculating internal training load in relation to sRPE (16). In consultation with the developer, the iSMARTtrain algorithm was adjusted to calculate Edward’s TRIMP, and to calculate Banister’s TRIMP for every recorded HR value.

Edwards’ TRIMP is derived from the duration spent within each of five zones in 10% increments of HR intensity from 50% to 100% of maximum heart rate (HRmax). Each zone has a corresponding weighting factor (between 1 and 5) to reflect the time spent at a lower intensity zone is not physiologically equal to that in a higher zone. The weightings used in Edwards’ TRIMP appear to have been derived arbitrarily, rather than from an experimental basis, and this has attracted criticism of its validity (43). Nevertheless, Edwards’ TRIMP is widely used and has been validated against other HR methods for determining internal training load such as Banister’s TRIMP (44-46).

Banister’s TRIMP was calculated using the following formula: Training impulse (arbitrary units) = duration of exercise (ΔHR)y. Where y = 0.64e_1.92ΔHR for males, and y = 0.86e_1.67ΔHR for females; ΔHR = (HRExercise - HRrest)/(HRMax - HRrest) and e = 2.718. The value y represents a weighting factor for each sex and was determined by generic lactic responses in trained individuals (42).
Both sRPE-TL and dRPE were calculated using Foster’s method (18). dRPE has been used in a number of studies and was developed to provide a more nuanced measure than the global measure of sRPE-TL (30, 47). The participants gave ratings of perceived exertion (RPE) in response to 5 different questions: How was your dance class?, How was the technical level?, How breathless did you get?, How was it for your arms?, How was it for your legs?. Each participant indicated their rating of exertion for the entire session on the Borg CR-100 centiMax scale 0-100, and for each question (36, 37). As described by Foster (18), sRPE-TL and dRPE was calculated by multiplying these RPE scores by the duration (in minutes) of the session.

Statistical analysis

An a priori power calculation was undertaken using the method described by Hulley et al (48). Assuming alpha = 0.05, power = 80%, and an expected correlation coefficient of at least 0.5 in magnitude, the minimum sample was calculated to be n=29. After derivation, values for Edwards’ and Bannister’s TRIMP, sRPE, and all indices of dRPE were imported into statistical software (SPSS v24, IBM Corp., USA) for analysis. Assumptions of normality were explored using visual inspection of boxplots, P-P and Q-Q plots, measures of skewness and kurtosis, and interpretation of the Shapiro-Wilk statistic. Some variables failed to meet the assumptions of normality and attempts at transformation were not successful, thus within-individual correlations between sRPE-TL/dRPE, and Edwards’ TRIMP, Banister’s TRIMP and %HR_{peak} were calculated using Spearman’s correlation coefficients. Hopkins’ scale of magnitudes was used to interpret correlation coefficients, where $r < 0.1$ is ‘trivial’; 0.1-0.29 as ‘small’; 0.3-0.49 ‘moderate’; 0.5-0.69 as ‘large’; 0.7-0.89 as ‘very large’; and >0.9 as ‘nearly perfect’ (49). Between session variability of sRPE and the differentials (cognitive/technical demands (RPE-T); breathlessness (RPE-B); leg muscle exertion (RPE-L); and upper-limb muscle exertion (RPE-A)) were analysed by calculating a coefficient of variation (CV%). In order to determine the contribution of each differential component of sRPE (RPE-T; RPE-B; RPE-A and RPE-L) on the overall sRPE, a multiple linear regression was calculated.
Results

A total of 34 participants were enrolled in the study and 31 contributed data (1 dancer withdrew after the fitness test, 2 dancers were injured at the time of data collection sessions). Descriptive characteristics of the participants are displayed in Table 1. A total of 174 individual sessions were recorded from a total of 202 available sessions across four different companies. Company 1 (n=5) completed 40 of 45 available individual sessions; Company 2 (n=10) 40 of 50; Company 3 (n = 10) 74 of 90; and Company 4, 22 of 30.

Table 1. Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Company1</th>
<th>Company2</th>
<th>Company3</th>
<th>Company4</th>
</tr>
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<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>3</td>
<td>10</td>
<td>7</td>
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<td>Male</td>
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<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>21±2.6</td>
<td>25.3±3.2</td>
<td>20.3±1.2</td>
<td>19.6±2.0</td>
<td>21.0±1.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.1±10.5</td>
<td>62.1±8.9</td>
<td>64.2±8.3</td>
<td>71.5±11.3</td>
<td>58.8±10.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.0±7.0</td>
<td>163.2±5.9</td>
<td>164.4±4.9</td>
<td>169.6±7.7</td>
<td>159.6±6.0</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>23.9±3.0</td>
<td>23.2±2.1</td>
<td>23.8±3.1</td>
<td>24.8±3.1</td>
<td>23.1±3.5</td>
</tr>
<tr>
<td>Total time dancing (h/week)</td>
<td>28.3±7.9</td>
<td>40.0±0.0</td>
<td>28.1±3.6</td>
<td>29.7±0.9</td>
<td>16.3±6.2</td>
</tr>
<tr>
<td>Session duration (mins)</td>
<td>89±12</td>
<td>87±6</td>
<td>88±10</td>
<td>83±6</td>
<td>113±9</td>
</tr>
</tbody>
</table>

Notes: values are mean ± standard deviation. 1. Company profile ‘1’ = professional, ‘2’ = full-time Year 2 students, ‘3’= full-time Year 1 students, ‘4’ = part-time Year 3 students.
Background information regarding the frequency of participation in different genres of dance for the entire sample is summarised in Figure 1. In this sample, ballet and jazz were the most popular genres in early childhood and were also the most studied technique throughout early adolescence. Contemporary dance training was the most studied technique in later adolescence.

![Figure 1. Heat map illustrating participants’ prior experience across dance genre. Notes: values in cells represent pooled frequency (n=31).](image)

Mean values for Edwards’ TRIMP, Banister’s TRIMP, %HRpeak, sRPE-TL, and dRPE for the entire sample and for the individual companies, across all sessions, are displayed in Table 2. Note that the mean session duration for Company 4 was 25% greater contributing to larger mean values for all variables aside from %HRpeak. For Company 4, dRPE-L and dRPE-B are somewhat divergent. dRPE-L is consistently rated higher than dRPE-B for all companies aside from Company 1 (professional).
Table 2. Mean values for indices of internal load and intensity

<table>
<thead>
<tr>
<th></th>
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<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edwards’ TRIMP(_{\text{AU}})</td>
<td>195±70</td>
<td>146±79</td>
<td>213±77</td>
<td>201±39</td>
<td>231±70</td>
</tr>
<tr>
<td>Banister’s TRIMP(_{\text{AU}})</td>
<td>101±42</td>
<td>83±46</td>
<td>115±47</td>
<td>98±30</td>
<td>121±39</td>
</tr>
<tr>
<td>%HR(_{\text{peak}})</td>
<td>94.4±4.4</td>
<td>94.7±4.2</td>
<td>94.1±4.6</td>
<td>93.3±4.5</td>
<td>97.3±2.7</td>
</tr>
<tr>
<td>sRPE-TL(_{\text{AU}})</td>
<td>347±250</td>
<td>475±181</td>
<td>243±288</td>
<td>313±167</td>
<td>623±175</td>
</tr>
<tr>
<td>dRPE-T(_{\text{AU}})</td>
<td>352±273</td>
<td>434±183</td>
<td>239±300</td>
<td>314±172</td>
<td>754±195</td>
</tr>
<tr>
<td>dRPE-B(_{\text{AU}})</td>
<td>294±247</td>
<td>467±198</td>
<td>204±268</td>
<td>231±150</td>
<td>547±222</td>
</tr>
<tr>
<td>dRPE-A(_{\text{AU}})</td>
<td>236±207</td>
<td>329±183</td>
<td>176±226</td>
<td>190±126</td>
<td>464±216</td>
</tr>
<tr>
<td>dRPE-L(_{\text{AU}})</td>
<td>339±265</td>
<td>430±186</td>
<td>245±290</td>
<td>287±173</td>
<td>708±211</td>
</tr>
</tbody>
</table>

Notes: values are mean ± standard deviation. 1. Company profile ‘1’ = professional, ‘2’ = full-time Year 2 students, ‘3’ = full-time Year 1 students, ‘4’ = part-time Year 3 students.; AU = arbitrary units; %HR\(_{\text{peak}}\) = percentage of maximum heart rate; sRPE-TL = session rating of perceived effort training load, dRPE = differentials of session rating of perceived effort (T=technical, B=breathlessness, A=arms and L=legs) (n=31).

Between session variability, as measured by the coefficient of variation, can be found in Table 3. Mean values for sRPE and the differentials of sRPE are also included. These are the means of the raw intensity ratings indicating session intensity (and not training load). Descriptors for mean values, as indicated by Borg (50) ranged from ‘moderate’ intensity for RPE-A for Company 3, to ‘very strong’ for RPE-T and RPE-L for Company 4. The mean intensity in all other cases was ‘strong/heavy’. Coefficient of variation values were predominantly between 30 to 50% reflecting the diverse and variable nature of dance class. For Company 1,3 and 4, RPE-T followed by RPE-L received the highest ratings, and RPE-L values were higher than RPE-B within Companies 2, 3 and 4.
Table 3. Mean values and between session variability for session and differential RPE

<table>
<thead>
<tr>
<th></th>
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<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>sRPE</td>
<td>51.5±11.1</td>
<td>54.9±7.1</td>
<td>55.1±12.9</td>
<td>43.8±10.2</td>
<td>55.4±6.5</td>
</tr>
<tr>
<td></td>
<td>31.8%</td>
<td>37.4%</td>
<td>36.1%</td>
<td>27.8%</td>
<td>26.7%</td>
</tr>
<tr>
<td>RPE-T</td>
<td>52.5±15.6</td>
<td>49.9±10.0</td>
<td>53.3±15.1</td>
<td>44.1±12.7</td>
<td>67.6±15.8</td>
</tr>
<tr>
<td></td>
<td>29.8%</td>
<td>37.0%</td>
<td>43.8%</td>
<td>21.9%</td>
<td>13.0%</td>
</tr>
<tr>
<td>RPE-B</td>
<td>43.8±13.2</td>
<td>53.3±6.5</td>
<td>46.7±12.5</td>
<td>32.7±9.5</td>
<td>49.5±12.9</td>
</tr>
<tr>
<td></td>
<td>47.3%</td>
<td>42.3%</td>
<td>58.2%</td>
<td>44.6%</td>
<td>37.5%</td>
</tr>
<tr>
<td>RPE-A</td>
<td>35.5±12.9</td>
<td>38.2±10.9</td>
<td>39.1±12.3</td>
<td>26.7±10.9</td>
<td>41.6±13.3</td>
</tr>
<tr>
<td></td>
<td>39.4%</td>
<td>50.1%</td>
<td>44.5%</td>
<td>32.4%</td>
<td>33.6%</td>
</tr>
<tr>
<td>RPE-L</td>
<td>51.4±16.6</td>
<td>49.8±12.1</td>
<td>56.5±14.3</td>
<td>40.1±14.1</td>
<td>63.3±18.0</td>
</tr>
<tr>
<td></td>
<td>29.6%</td>
<td>37.8%</td>
<td>35.5%</td>
<td>29.4%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

Notes: values are mean ± standard deviation (SD) and coefficient of variation (CV%). 1. Company profile ‘1’ = professional, ‘2’ = full-time Year 2 students, ‘3’ = full-time Year 1 students, ‘4’ = part-time Year 3 students.; sRPE = session rating of perceived effort; RPE-T = differential session rating of perceived effort for technical; RPE-B = differential session rating of perceived effort for breathlessness; RPE-A = differential session rating of perceived effort for arms; RPE – L = differential session rating of perceived effort for legs. (n=31).

The within-individual correlations between sRPE-TL and the differentials (dRPE-T, dRPE-B, dRPE-A and dRPE-L) with Edwards’ TRIMP are displayed in Figure 2 Panel A; with Banisters’s TRIMP, Figure 2 Panel B; and with %HRpeak in Figure 2 Panel C. The highest within-individual correlation was dRPE-B for both Edwards’ and Banister’s Trimp.
Figure 2. Magnitude of mean within-individual correlations between sessions rating of perceived sRPE-TL and dRPE with heart-rate derived measures of training load and intensity (n=31). Panel A: Edwards’ TRIMP. Panel B: Banister’s TRIMP. Panel C: %HRpeak (percentage heart rate peak). Notes: dRPE (T=technical, B=breathlessness, A=arms and L=legs). Error bars are ±95% confidence limits. Descriptors for magnitude of correlations are based on Hopkins (49).
A multiple regression was run to predict sRPE from its differential components RPE-T, RPE-B, RPE-A, RPE-L. The multiple regression model statistically significantly predicted sRPE, $F(4, 26) = 27.894, p < 0.001$, adjusted $R^2 = 0.78$. Two variables, RPE-B and RPE-L, added significantly to the prediction, $p < 0.05$. Regression coefficients are displayed in Table 3.

### Table 4. Summary of multiple regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE$</th>
<th>$\beta$</th>
<th>95% CI</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>16.567</td>
<td>3.549</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPE-T</td>
<td>0.102</td>
<td>0.109</td>
<td>0.143</td>
<td>-0.121 to 0.325</td>
<td>0.143</td>
</tr>
<tr>
<td>RPE-B</td>
<td>0.399</td>
<td>0.130</td>
<td>0.472</td>
<td>0.131 to 0.667</td>
<td>0.005</td>
</tr>
<tr>
<td>RPE-A</td>
<td>-0.098</td>
<td>0.129</td>
<td>-0.113</td>
<td>-0.363 to 0.167</td>
<td>0.454</td>
</tr>
<tr>
<td>RPE-L</td>
<td>0.303</td>
<td>0.120</td>
<td>0.451</td>
<td>0.056 to 0.550</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Notes: $B =$ unstandardized regression coefficient; $SE =$ Standard error of the coefficient; $\beta =$ standardized coefficient; $p =$ calculated probability; CI = confidence intervals. RPE-T = differential session rating of perceived effort for technical; RPE-B = differential session rating of perceived effort for breathlessness; RPE-A = differential session rating of perceived effort for arms; RPE-L = differential session rating of perceived effort for legs.

## Discussion

### Aim and main findings

Training load is a crucial variable in understanding overuse injury etiology and in the formulation of injury prevention strategies (8). As a measure of internal training load, sRPE-TL has been widely investigated and validated in numerous sports and has been used in overuse injury load studies (10, 16). In dance, just one study of pre-professional dancers, has investigated the validity of sRPE-TL via its convergent validity with Edwards’ and Banister’s TRIMP (24). As a measure, sRPE-TL has been refined further through the use of sRPE-TL differentials (dRPE). This study is the first in dance to examine sRPE using dRPE components. Thus, the primary aim of this study was to investigate the relationship of sRPE and differential sRPE with Edwards’ and Banister’s TRIMP across several companies of contemporary dancers with different levels of experience. The magnitude of correlation between sRPE-TL
for both TRIMPs was *moderate*. Of session and differential ratings, dRPE-B had the strongest correlation with both Edwards’ and Bannister’s TRIMP. A secondary aim was to explore how the various differentials contribute to sRPE-TL, and here, dRPE-B and dRPE-L were found to be the only differentials that contributed significantly to sRPE-TL.

In contrast to Jeffries et al (24), who found large correlations between sRPE-TL (r=0.59 to 0.72) and the other objective measures (Edwards’ and Bansiter’s TRIMP, and %HRpeak) with pre-professional dance students, only moderate correlations were observed in this sample. A number of reasons may explain the difference between Jeffries et al and the present findings, these include differences in: the type of class, a skills focus, as well as intermittency effects, high-intensity effects, and participant characteristics.

*Type of class*

Differences in the typology of training in sports has been proposed to explain the variance in correlations found between studies of this kind (10). In this study the between session variance indicates a high degree of variability of dancers’ experience of session intensities. Dance and contemporary dance is considered to be diverse and intermittent ranging in moderate to high intensities (31). As it is not a codified technique contemporary dance is particularly variable in form (51). Comparing sRPE-TL values for dance class with those in Jeffries et al (24) indicates that the contemporary dancers of this sample undertook comparable workloads.

*Skills focus*

Lower correlations with Banister’s TRIMP have been reported in a number of studies when training focused on skill development (52, 53). As dance is a skill-oriented activity this may explain some of the variance of sRPE-TL and the lower degree of correlation with the objective measures. Focusing on skill may result in an increase in intermittency, however, the temporal nature of training is not specified in these studies. Based on field observation, it was noted that Companies 3 and 4 spent more time breaking movements down into components and rehearsing skills and individual movements than Companies 1 and 2.
Intermittency effects
Correlations between sRPE-TL and Banister’s or Edwards’ TRIMP have been found to be weakened in a number of studies when the training intensity is intermittent (28, 54). This may be due an increased level of difficulty in the self-perception of intensity when training is discontinuous. One study found a higher degree of correlation when rest periods were removed from the load calculation suggesting perhaps that rest is difficult to account for when rating intensity (55). The duration of rest periods was also found to be important in soccer with longer breaks between activity reducing the magnitude of correlation between sRPE-TL and Banister’s TRIMP (21). The intermittent nature of contemporary dance may also have been a factor influencing the degree of correlation between Edward’s and Banister’s TRIMP and sRPE-TL here. The degree of intermittency within the sample was not quantified but was based on field observations of the principal researcher and was noted to range from continuous to highly discontinuous. Company 4 in particular was noted to have the highest degree of intermittency with their class with an almost 50% split between active movement and discussion and feedback. For Company 1 and 2 the classes were more continuous in nature.

High-intensity effects
Decreased associations between sRPE-TL and Banister’s and Edward’s TRIMP may be due to high-intensity bursts of activity which utilise anaerobic energy systems or a combination of aerobic and anaerobic systems. More explosive activity such as jumps also result in greater biomechanical stress. Contemporary dance has been found to utilise both aerobic and anaerobic systems (56). Heart rate does not clearly reflect anaerobic contributions or biomechanical stress (29, 30, 57).

Participant characteristics
While the design was not powered to enable inter-company analysis aside from descriptive data, the approach to sampling was intended to encompass a diverse range of contemporary dancers across experience and expertise. In several sports, the reliability of sRPE-TL was found to be affected by the level of experience and competency of the participants. For example, in a study of competitive swimmers, the relationship between sRPE-TL and external loads became stronger with increasing years of experience and practice (26). Likewise, in a study of soccer, the magnitude of
the relationship between sRPE-TL and HR derived measures increased as participants progressed from their first to second year of playing within the same team (58). In this sample there were a range of experience levels from professionals to Year 1 bachelor degree dance students, and those who have danced since early childhood and others who have only recently begun to dance. Frequency of training experience also contributes to the ability to rate session intensity (59). Frequency of training also varied across the sample, with Company 1 training 40 hours per week compared to Company 4 training ~16 hours and is more diverse than the sample of Jeffries et al. (24). Brink et al. suggest that younger, less experienced, and therefore less competent athletes may require a greater degree of familiarisation to ‘calibrate’ their perception of exertion. Although objective methods for determining competency in dance are available they were not employed to describe participants here, as this was beyond the scope of this study (60). Rather, the competency level within the sample was based on field observations of the principal researcher, an experienced contemporary dancer and choreographer. Within the sample it ranged from novice through to highly adept. Consequently, participants in this study who were younger, less experienced, or training less frequently may have required more sessions for familiarisation and this is a potential weakness of this study.

**Differential components of sRPE-TL**

The highest magnitude of correlation between objective and subjective measures was between the differential for breathlessness (dRPE-B) and Edwards’ and Banister’s TRIMP. The two differentials, RPE-B and RPE-L, contribute significantly to sRPE as demonstrated by the regression analysis. However, dRPE-L does not display the same consistency of correlation with Banister’s TRIMP. The use of differential ratings, although not widely adopted, has been investigated in a small number of studies (30, 33, 47). In particular, RPE-B and RPE-L have been shown to represent different aspects of effort (30, 33). RPE-B is more reflective of central drivers such as cardio-respiratory demand (30), while RPE-L is more likely to be indicative of local biomechanical stress and metabolite build-up such as lactate associated with anaerobic pathways (29). Heart rate based methods for deriving internal load are therefore more reflective of the cardiovascular system (53, 57, 61), and this explains why dRPE-B had the higher correlation with Edwards’ and Banister’s TRIMP. Thus, dRPE-B appears to be an appropriate measure for assessing cardio-respiratory
demand despite the diversity in class typology and participant characteristics. dRPE-B would be a simple and practical approach to assessing cardio-respiratory load without recourse to HR monitors or other wearable technologies that may be impractical in contemporary dance.

The differential dRPE-T, had only small correlations with the Edwards’ and Banister’s TRIMP and with %HR_{peak}. Yet, RPE-T was consistently rated the highest across the companies apart from Company 2 who rated RPE-L above it. This disassociation suggests that dance is a technically demanding discipline, but that the degree of technicality is not closely associated with the cardio-vascular demand. Weston et al. (33) also found this to be the case in their study of Australian Football. Regarding dance, this makes sense, as some movements or choreography require a high degree of coordination and concentration but do not require much physical effort. Concentration and focus have been previously demonstrated to be more independent of the external loads being applied (61).

Of the differentials rating physical demand, RPE-L was rated higher than for RPE-B for Companies 2, 3 and 4. Company 1 ratings were closer with RPE-B slightly above RPE-L. Despite the ratings for RPE-L being higher or similar to RPE-B, dRPE-L correlated poorly with the Edwards’ and Banisters’ TRIMP and with %HR_{peak}. This suggests that dRPE-L represents a dimension of physical effort dissimilar to that of dRPE-B. This is in agreement with other several studies that have shown that sensations arising centrally from breathing and those arising peripherally in the legs can be independently perceived and represent different loading pathways (29, 30, 34, 62). Specifically, dRPE-L represents a peripheral load pathway from biomechanical stress and local muscle metabolites such as lactic acid from anaerobic respiration (29). Thus, sRPE-TL and dRPE-L include this information but this is not reflected in the objective measures derived from HR. Likewise, dRPE-B reflects the sensations of breathing which are arising centrally and are associated with cardiovascular load as demonstrated in this study and elsewhere (29). That RPE-L is reported higher than RPE-B is a finding that is consistent with other studies reporting perceived sensations arising in the legs as more dominant than centrally arising sensations (33, 34, 62).
**Percentage heart rate peak**

Percentage HR\textsubscript{peak} is not a measure of internal training load, but is rather an index of training intensity (63). This measure reflects the highest intensity reached relative to an individual’s HR maximum, however, it does not reflect how frequently this occurs and therefore was not expected to correlated highly with sRPE-TL and dRPE. The degree to which %HR\textsubscript{peak} correlated with sRPE-TL was moderate and is lesser in magnitude to that reported by Jeffries et al. (24) where the correlation was strong. Similarly, Scott et al. (64) also found strong correlations between sRPE-TL and %HR\textsubscript{peak} in their sample of Australian football players.

**Methodological issues**

There is little guidance in the literature as to what constitutes an appropriate magnitude of correlation to validate sRPE against other criterion measures. A recent review suggests that acceptable ranges of correlation between sRPE and other measures, reported across many sporting applications, range from moderate to nearly perfect (16). The acceptance of moderate correlations is perhaps due to the obvious advantages in convenience when applying sRPE in the field. There is no simple alternative method for quantifying training load. Accepting moderate correlations may represent a necessary trade-off between practical utility and validity.

In this study, the dance specific aerobic fitness test (DAFT) (38) was used to elicit a HR\textsubscript{max}. However, it is important to note that the DAFT was not specifically designed for this purpose. According to its developer, the DAFT will in most instances, achieve a HR\textsubscript{max} because most dancers do not display a high level of aerobic adaptation (personal communication Wyon, 2018). However, it is possible that a HR\textsubscript{max} for some individuals with higher levels of fitness may not be obtained. Similar to Perotta (65), in the case where a higher HR was observed in the field, the higher value was substituted as the new HR\textsubscript{max} in data analysis. There is a possibility that a HR\textsubscript{max} might not have been obtained for some individuals from the test, or in the field. In such cases this would lead to higher HR derived loads and intensities. A dance specific maximum heart rate protocol has not been described, but would be useful for future studies that use Banister’s or Edwards’ TRIMP.
According to Foster, Edwards’ TRIMP is better for measuring intermittent training (18). This assessment appears to be based on the assumption that Banister’s TRIMP requires steady-state exercise to be accurate. This is because HR means were used to calculate Banister’s TRIMP in steady-state, however, a methodology for non-steady state is also provided which does not use session means (41, 42). HR means for intermittent sports are considered invalid (66, 67), although a number of studies appear to have used session HR means with Banister’s TRIMP in their studies of intermittent sports (21, 53, 54, 68). In this study, Banister’s TRIMP calculation was applied to every HR value, and therefore represents a more comprehensive calculation of internal load than is possible with HR zones. Edwards’ TRIMP uses HR zones with arbitrary increments which means that when heart rate is below 49%HRmax a nil training load results. Whereas, in the same scenario Banisters’ calculation would yield a value, albeit small. Therefore, in this study Banister’s TRIMP should be considered to be the more sensitive measure, however, both methods are presented to permit comparison with other studies. Unfortunately, Jeffries et al (24) appear to have used averages in their Banister’s TRIMP calculation limiting a direct comparison with their results. Likewise, direct comparison with their Edwards’ TRIMP calculations is not possible as they have used a modified version.

The recommendation of waiting 30 minutes to administer the sRPE or dRPE questionnaires after sessions to avoid latency affects (30) was not possible because, for logistical reasons related to class timetabling, the maximum available time was ~15min. However, Uchida et al (69) have shown that accurate measures can be made as early as 10 minutes following exercise.

Limitations
A number of limitations were identified in this study. Firstly, this study did not measure external loads. The use of external load measurement is important because they impact directly on internal load measures (10). In a recent meta-analysis for team sports, external load measures correlated better than internal load measures with sRPE (10). Understanding the relationship between external and internal loads has the potential to improve the modulation of load to optimise performance and mitigate risk of overuse injury. Accelerometers may offer a convenient way to quantify external load in dance and have recently been used to do so (24). In this instance, external
loads were found to correlate better with the internal load measures from Edwards’ and Banister’s TRIMP than with sRPE.

A second limitation is that the class typology, including work to rest ratios, jump volume, or movement characteristics, although recorded by video, has not been analysed as this was beyond the scope of the present study. This analysis could be used to explain more precisely why the magnitude of correlations were smaller than those found by Jeffries et al. (24).

A third limitation is that other variables known to affect sRPE were not addressed. Session RPE as has already been demonstrated, appears to be the product of many influences and is not easily explained by a single measure (10). Jeffries et al (24) found that a combination of internal and external load measures combined with non-load factors such as sleep quality and muscle soreness explained variance in sRPE better than any single measure. However, the influence of non-load factors on sRPE may be small (16).

Future Research
The use of multiple objective measures for different components of internal training load as criterion measures in establishing the validity of sRPE-TL is a recommendation for future research. An investigation of the relationship between objective measures, such as biomechanical load and anaerobic load and sRPE-TL, and differentials of sRPE, that reflect peripherally driven exertion is recommended (29). In particular, the relationship between dRPE-L and relevant objective measures of biomechanical (eg jump-load (70)) and anaerobic load (20) would be useful.

Conclusions
This study provides further evidence that differential ratings of perceived exertion represent different sensory input and different dimensions of effort such as those that arise centrally (RPE-B), those that arise peripherally (RPE-L, RPE-A) and those that are cognitive (RPE-T). This appears to be the first study to use dRPE in dance and demonstrates that sRPE-TL is most influenced by dRPE-B and dRPE-L. The lower correlations between sRPE-TL with Edwards’ or Banister’s TRIMP observed in this
study may be due to a number of reasons (or any combination of reasons) such as
dancers of a different levels of experience or competency, a class typology which is
skill-centric, or which is highly intermittent, or has high-intensity anaerobic activity.
The use of differentials of sRPE appears to be useful in monitoring training load in
contemporary dance. In particular, dRPE-B rather than sRPE-TL can be considered
the more appropriate measure of cardiorespiratory load and could be of use in future
dance injury prevention studies.

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SECTION III APPENDICES
Matt Smith
4b Mackwood Place
Birkdale
Auckland 0626

8.12.16

Kia ora Matt,

Your file number for this application: 2016-1073
Title: Relationship between different measures of physical intensity in contemporary dance.

Your application for ethics approval has been reviewed and approved by the Unitec Research Ethics Committee (UREC) for the following period:

Start date: 21.11.16
Finish date: 21.11.17

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.

2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely,

[Signature]

Nigel Adams
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida
APPENDIX A – PARTICIPANT CONSENT FORM

PARTICIPANT CONSENT FORM

Research Project Title:

**Relationship between different measures of physical intensity in contemporary dance**

I have had the research project explained to me and I have read and understand the information sheet given to me.

I understand that:

- I don't have to be part of this research project should I chose not to participate and may withdraw at any time.
- I have the right to withdraw my results up until 5pm the day after the final testing session.
- Everything I say is confidential and none of the information I give will identify me in any reports. I understand that the only people who will have access to my personal information and results will be the researchers.
- All the information gathered in the research will be stored securely on a computer or within a locked filing cabinet at Unitec for a period of 5 years, at which point it will then be destroyed.
- My de-identified data may be used for publications or further investigations but my name or any personal information will not be used in the publication of the results.
- I am able to request a plain language copy of the research findings should I so wish.
- I will be required to wear a heart rate monitor and an accelerometer during my contemporary dance class once per day for a week.
- The taping of the accelerometer may cause some slight discomfort whilst wearing and on removal.
- I will be required to do a physical test to estimate my maximum heart rate.
- I will be required to determine my resting heart rate on 3 days in the morning on waking.
- I will be required to rate the difficulty of the class using a questionnaire 15 minutes after class.
- A video recording will be made for each class and that this is solely for research purposes and will be stored securely on a computer or within a locked filing cabinet at Unitec for a period of 5 years, at which point it will then be destroyed.
I have had time to consider everything and ask any questions and I give my consent to be a part of this project.

Participant Name: ……………………………………………………………………......

Participant Signature: ………………………….. Date: ……………………………

Project Researcher: ……………………………. Date: ……………………………

UREC REGISTRATION NUMBER: (2016-1073)
This study has been approved by the UNITEC Research Ethics Committee from 21 November 2016 to 21 November 2017. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Participant Information Sheet

Relationship between different measures of physical intensity in contemporary dance

My name is Matthew Smith. I am currently enrolled in the Master of Osteopathy degree at Unitec. You’re invited to participate in a research project about the physical intensity involved in contemporary dance.

What is this project about?
We are investigating several different measures of physical intensity to learn more about the efforts involved in dancing. The measures are heart rate (using a heart rate monitor), your perception of effort (using a questionnaire), and how much you move (using an accelerometer – a watch-like device that records movement).

What will I need to do during the study?
During the study, you’ll be asked to wear a heart rate monitor and an accelerometer. This involves wearing an elastic chest strap during classes. About 15 minutes after each class we will also ask you to provide a rating of how breathless you might have felt, how technically challenging, and how hard was it for your lower body and upper body.

What it will mean for you?
If you agree to participate in the study your involvement will involve:
1. A meeting at which we’ll collect some basic information about your dancing history, and we will also brief you about the project where you will be familiarised with the equipment and the questionnaire for rating the session.
2. We will do a standardized fitness test for dancers where we use the heart rate monitor to determine your maximum heart rate. This will take 20 minutes. It involves simple dance movements in an easy dance sequence, which you will learn before the test. The test is in five stages each four minutes long and set to a specific tempo. The tempo increases throughout the test.
3. You will also be given the heart rate monitor to take home to record your heart rate at rest, which will be done when you wake up in the morning for 3 days.
4. For one contemporary class per day over the course of a week you’ll be wearing a heart rate monitor and an accelerometer (a device about the size of a matchbox). 20 minutes before class we will need you to put the equipment on and to test that it is working. 15 minutes after class the paper questionnaire will be given for you to rate the class and will take less than 2 minutes.

How do I give consent?
If you agree to participate, you will be asked to sign a Consent Form. This does not stop you from changing your mind if you wish to cease participating in the project for any reason and you may withdraw your data up to 5pm the day following each day of data collection.
**Is the information I give confidential?**
Yes, any information that may identify you will be kept completely private and confidential. All information that is collected from you will be stored on a password-protected file and only the researcher and supervisors will have access to this information. This information will be kept for 5 years then destroyed.

**Can I get a copy of the research findings?**
Yes, you’d like to receive a plain language summary of the research findings please let us know by email: Matt Smith: smeeth@gmail.com

**Who do I contact with questions?**
Please contact us if you need more information about the project. At any time if you have any questions about the research project please contact one of us:

**Primary researcher:**
Matthew Smith  
Health Care, Unitec Institute of Technology  
Tel: 022 321 3571  
Email: smeeth@gmail.com

**Principal Supervisor:**
Rob Moran  
Health Care, Unitec Institute of Technology  
Tel: 09 815 4321 ext 8197  
Email: rmoran@unitec.ac.nz

**UREC REGISTRATION NUMBER: 2016-1073**
This study has been approved by the Unitec Research Ethics Committee from 21 Nov 2016 to 21 Nov 2017. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 8551). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
APPENDIX B – QUESTIONNAIRE FOR SESSION AND DIFFERENTIAL RATINGS OF PERCEIVED EFFORT

Name
Date
How was your dance class?

Absolute maximum

"Maximal" Max X
Extremely strong

Very strong

Strong Heavy

Moderate

Weak Light

Very weak

Extremely weak

"Minimum" Just noticeable

Nothing at all
How was the technical level?

- **Absolute maximum**
- "Maximal" Max X
- Extremely strong
- Very strong
- Strong Heavy
- Moderate
- Weak Light
- Very weak
- Extremely weak
- "Minimum" Just noticeable
- Nothing at all
How breathless did you get?

- Absolute maximum
- "Maximal" Max X
- Extremely strong
- Very strong
- Strong Heavy
- Moderate
- Weak Light
- Very weak
- Extremely weak "Minimum" Just noticeable
- Nothing at all
How was it for your arms?

- **Nothing at all**
- **Just noticeable**
- **Very weak**
- **Light**
- **Moderate**
- **Strong**
- **Very strong**
- **"Maximal" | Max X**
- **Extremely strong**
- **Absolute maximum**
How was it for your legs?
Full name of author: Matthew William Smith

ORCID number (Optional): ..............................................................

Full title of thesis/dissertation/research project ('the work'):
The relationship between differential and session ratings of perceived exertion with heart rate derived measures of internal load in contemporary dance - An Observational Study

Practice Pathway:

Degree: Masters of Osteopathy

Year of presentation: 2018

Principal Supervisor: Prof. Moran

Associate Supervisor: Catherine Bacon

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Copyright Compliance:
I confirm that I either used no substantial portions of third party copyright material, including charts, diagrams, graphs, photographs or maps in my thesis/work or I have obtained permission for such material to be made accessible worldwide via the Internet.
Declaration

Name of candidate: MATTHEW WILLIAM OLIVER SMITH

This research thesis entitled *The relationship between differential and session ratings of perceived exertion with heart-rate derived measures of internal load in contemporary dance: An observational study*, is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

Principal Supervisor: Rob Moran

CANDIDATE'S DECLARATION

I confirm that:

- This thesis represents my own work,
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies,
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2017-1073

Candidate Signature:  
Date: 24.4.18