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Kjetil Låstad Rønneberg

Seasonal training load quantification in men's Norwegian premier league football

Differences in measured external- and internal training load within microcycles and throughout the competition phase

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Forord

Det har aldri falt meg inn at eventyret på Norges idrettshøgskole skulle ta slutt på denne måten. For det er nettopp det NIH-hverdagen har vært de siste seks årene – et eventyr. Jeg står nå igjen med en mastergrad, faglig kunnskap og minner for livet, men aller viktigst – bekjentskapet til alle de fantastiske personene jeg har møtt. Tusen takk, dere har gjort årene på NIH til de seks beste årene i livet – så langt. Nå venter nye utfordringer.

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Abstract

Introduction: Due to the complex match scheduling in football, a proper periodization strategy is necessary to avoid fatigue and injuries and optimize physical performance prior to match play. The purpose of this study was to quantify and examine differences in training load and intensity within microcycles and between mesocycles throughout the competition phase.

Methods: A GPS unit with a built-in accelerometer (Catapult OptimEye X4) and self-reported internal load (RPE) were used by elite Norwegian premier league players (n=10; Age=27 ± 3) throughout the 2018 competition phase. Data was collected on MD (match day)-4, MD-3, MD-2 and MD during normal microcycles containing 1 game and 4 training sessions for external (17 microcycles, n = 563 samples) and internal load (17 microcycles, n = 475 samples). Full-team differences in training load and intensity within microcycles and between mesocycles (4x5week blocks) were examined. Analyzes were performed for total distance covered (TDC), high-speed running distance (HSRD), sprint distance, PlayerLoad™ (PL™), RPE and sRPE, all in absolute values and relative to match play.

Results: MD showed higher TDC, HSRD, sprint distance, PL™, RPE and sRPE compared to all training days (Effect size: 2.9-13.9). Differences between MD-2, MD-3 and MD-4 was also present: higher HSRD and sprint distance closer to MD (MD-2 > MD-3 > MD-4) and lower values for TDC, PL™ (MD-2 < MD-4 < MD-3) and internal load (MD-2 < MD-3 < MD-4), was observed closer to MD. Differences were also observed between mesocycles: higher TDC in mesocycle 5 compared to the others (Effect size: 0.5-0.6) and lower HSRD and sprint distance in mesocycle 6 compared to the others (Effect size: 0.1-0.8). Lower TDC·min^{-1} and PL™·min^{-1} in mesocycle 3 compared to the others were also observed (effect size: 0.7-3.3).

Conclusion: Day-to-day differences in measured TL and intensity within microcycles were observed. Besides an increase in HSRD and SPRINT, a decrease in other variables preceding match play were observed, suggesting a tapering strategy towards MD. Differences between mesocycles were also prominent, with a decrease in HSRD and sprint distance in the last mesocycle compared to the others. Meso 3 produced the lowest intensity for TDC·min^{-1} and PL™·min^{-1} despite a different pattern for the corresponding TL variables, suggesting duration to be the main altered component.

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1. Introduction

Football is an intermittent team sport consisting of several periods of repeated and highly intensive actions. During competitive match play, there is either a change of speed or direction every 5th second (Rampinini et al., 2011). The competitive phase of the season usually extends over 9-10 months, and may consist of several games within a week with participation in several competitions during these months (Anderson et al., 2016). Thus, a microcycle in football has been considered to benefit from a "multiple peaking" periodization strategy to repeatedly perform at a high level in all matches across the season (Akenhead, Harley, & Tweddle, 2016).

In addition with football being one of the most popular sports in the world, football as a field of research has expanded further in recent years by assessing physical demands and loads elicited during training sessions (Malone et al., 2015). The elicited load during training sessions is often referred to as training load (TL), and has commonly been categorized into two dependent categories; The external training load (E-TL), which is any external stimulus applied to the athlete that is measured independently of their internal characteristics, and the internal training load (I-TL), which is each individuals' response to the associated E-TL (Soligard et al., 2016). Today, there are methods applied in football to measure and monitor players in professional sport with the aim being to minimize injury occurrence, prevent deconditioning and increase performance, and is commonly used by coaches, practitioners and researchers (Akenhead & Nassis, 2016).

In more recent years, research regarding seasonal TL quantification in elite football from different national leagues has been given increased attention. In theory, the pre-season is usually utilized to enhance physical abilities, while the competitive phase commonly focuses on the technical and tactical aspects of the game, as well as maintaining the physical capabilities (Malone et al., 2015; Oliveira et al., 2019). However, little is known about the periodization strategies in Norwegian elite football, both on microcycle and mesocycle levels. Moreover, field testing is commonly used for assessing physical capacities, but with the current practice in TL monitoring, the continuous quantification of both E-TL and I-TL may provide more sensitive data regarding each players' adaptions to a planned program (Akenhead & Nassis, 2016).

Notably, the focus on physical attributes are exclusively one out of many abilities that affects the advanced game of football, and the variation in TL and match load for one team is likely influenced by coaching tactics, opposition, situation, strategies, and different demands in different national league competitions. Even though technical and tactical abilities are probably of superior importance, a sufficient physical baseline may be required to apply and further develop their technical and tactical skills.

Purpose of the study

Based on results from the available literature, the purpose of this thesis was to quantify both I-TL and E-TL in Norwegian professional football during the competitive phase of the season, as well as the relationship between them. With the use of global positioning systems (GPS) and accelerometer devices for external load and session rating of perceived exertion (sRPE) for internal load, the thesis will try to answer how the periodization strategies for TL are applied throughout the season on both microcycle and mesocycle levels. Findings from this particular thesis may provide a better understanding of the physical demands for football players competing in the Norwegian premier league, and potentially augment knowledge in this field of research on seasonal TL quantification in team sports. Furthermore, the study may inform whether the load elicited during the season is 1) sufficient for maintaining physical performance, 2) enhances physical performance, or 3) fails to maintain physical performance.

Research questions

1) Are there any day-to-day differences in measured training load and intensity within microcycles during the competition phase?

2) Are there any differences in measured training load and intensity in different mesocycles throughout the competition phase?

3) Are there any differences in the relationship between the external training load and internal training load throughout the competition phase?

2. Theory

2.1 The game of football

Football (in some countries called soccer) is the most popular sport in the world in terms of commercial popularity and active players (Pedersen, 2018). There are several male and female professional leagues, and the international football association includes approximately 211 member associates (FIFA, 2018). Being one of the member associates, the Norwegian Football Association had a total of 371910 members in 2017, making it the biggest participating sport in the nation (NFF, 2018). The 2014 UEFA Champions League final had an average audience of 165 million viewers (UEFA, 2014), and the FIFA World Cup had a total audience of 1.013 billion (FIFA, 2015). These national and international figures underline the magnitude as well as the attractiveness of the sport. A game of football is played between two teams of 11 players, including one goalkeeper, with the aim being to score more goals than the opponent (IFAB, 2018).

During competitive match play, each player have a relative pitch area of approximately 320 m^2 (Olthof, Frencken, & Lemmink, 2018). Depending on possession of the ball, teams will alter between defensive and attacking phases, with a transition phase in between. On average, possession change every 15 seconds (Wymer, 2004), and only 1.2-2.4% of the total distance covered (TDC) by players are in possession of the ball (Di Salvo et al., 2007). Moreover, due to the limited amount of substitutes each match, all players have important roles in both defensive and attacking phases of the game.

2.2 Fundamentals of periodization and strategies in sports

The fundamentals in periodization is to achieve the greatest physiological capacity as possible and prepare the athlete to maximize their potential in competition (Bompa & Buzzichelli, 2018). The traditional periodization strategies, such as linear and block periodization, is often used to focus on one or a few physical abilities (e.g. strength, endurance and speed) in a period to maximize the outcome and performance in competitions (Bompa & Buzzichelli, 2018).

TL can be adjusted by manipulating the intensity, the duration and the frequency of training sessions, as well as the recovery time between each training session (Hallén &

Ronglan, 2011). Periodization assumes that different levels of TL causes different biomechanical and physiological responses (Brink, Frencken, Jordet, & Lemmink, 2014). Thus, the aim of periodization is to appropriately manipulate training contents to optimize training outcomes and competitive performance (Reilly, 2005). Periodization states that performance will initially decrease if the load is greater than the capacity of the player. However, if the player has a sufficient recovery period the capacity of the player augments beyond the baseline level, which is an effect known as supercompensation. This is considered the fundament of periodization (Brink et al., 2014). However, a non-optimal periodization may cause implications. If too much elicited TL is followed by too little recovery, players may suffer from overtraining. Oppositely, undertraining occurs when TL stimulus fails to exceed the capacity of a player (Brink et al., 2014). An optimal periodization for each individual can be achieved with TL monitoring, but despite an increase in research in this area much of what is known comes from personal experiences and anecdotal information or remains unpublished (Bourdon et al., 2017).

Previous research regarding periodization and unloading to increase athlete readiness (i.e. performance) mostly relates to individual sports. The gradual unloading towards competition is usually termed as tapering (Bompa & Buzzichelli, 2018; Reilly, 2007). Findings suggest a tapering model of decreased TL over the course of 7 to 28 days prior to competition (Mujika, Padilla, Pyne, & Busso, 2004). However, periodization in team sports is complex compared to individual sports. Firstly, a tapering period with the length of that magnitude is not possible in football due to the competition scheduling. The competitive phase in football is long with many competitions (i.e. matches) and if the aim is to have each player super compensated in each competition, a proper periodization strategy is necessary (Walker & Hawkins, 2018). Moreover, the training content in football is widely determined by the nature of the game, and the physical stress elicited on the players is often considered as a response to the technical and tactical actions (Los Arcos, Mendez-Villanueva, & Martinez-Santos, 2017). The majority of training drills consist of game play collectively with the team and thus, the TL is often determined by other factors such as the performance of the whole team as well as the individual position specific characteristics (Los Arcos et al., 2017). A periodization strategy known as “tactical periodization” is a form of linear periodization in which the aim is to maintain or enhance physical capacities which is important for performance in competitions that occur several times throughout the competition phase, (Robertson & Joyce, 2015).

A typical week with tactical periodization can be expressed in relation to the number of days until match day (MD+/MD-). Following MD, MD+1 and MD+2 usually contains active and/or passive restitution. Onwards, MD-4 and MD-3 are training sessions in which the aim is to overload the players, then followed by a decrease in TL on MD-2 and MD-1 preceding MD to ensure supercompensation and increase the readiness of the players (figure 2.1).

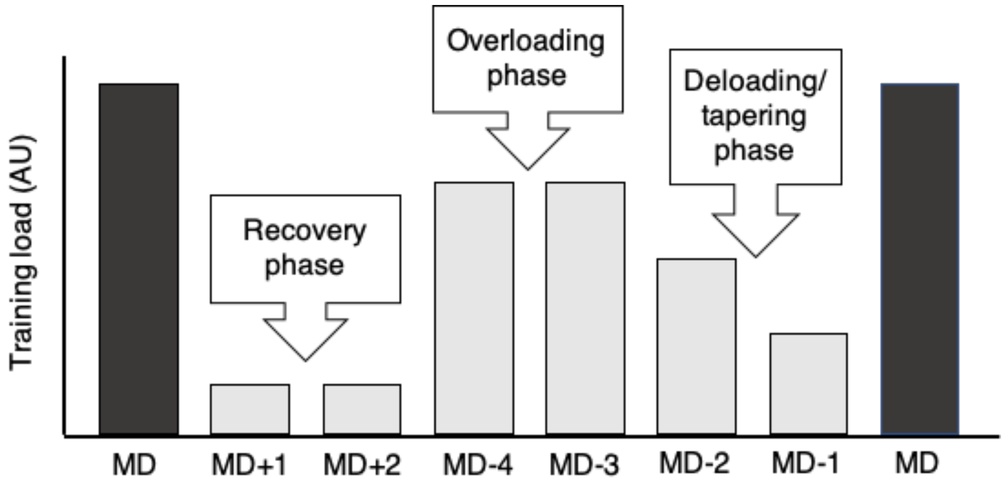

Figure 2.1: *Illustration of how tactical periodization can be applied in elite football. Abbreviations: AU = Arbitrary unit, MD = match day, +/- = days in proximity to match day.*

2.3 Training load in football

Much has evolved in terms of tactical, technical, psychosocial and physical demands in football (Los Arcos et al., 2017). This may have led to a supplementary augmentation of the total TL produced on the players (Bush, Barnes, Archer, Hogg, & Bradley, 2015). Athlete monitoring can be used to decrease the risk of overtraining/undertraining, illness and injury (Bourdon et al., 2017). Additionally, proper load monitoring can assist coaches in decision makings considering player availability etc. (Bourdon et al., 2017). Exposure to high TL and a saturated match program with poorly managed TL monitoring has shown to be a significant injury risk factor (Soligard et al., 2016). This may particularly occur when the players are exposed to rapid changes in the match scheduling, returning from injury and when extreme variations in TL during microcycles occur (Schwellnus et al., 2016). The importance of monitoring athletes' TL is in many cases crucial; it can provide insight in whether athletes are adapting to a training program, understanding their individual responses to training and assessing fatigue and thus, evaluate their associated need for recovery. It is common to quantify both TL in football, and may be used as a tool to describe the physical demands in football (Akenhead & Nassis, 2016). Additionally, it is important in sports to quantify both TL categories; when the I-TL is not considered the individual aspect is excluded due to an intra variability in internal responses to the same E-TL (Schwellnus et al., 2016).

The monitoring of I-TL is more sensitive and consistent to determinate acute and chronic differences in athlete fitness in response to the external load (e.g. biological adaptions), but it does not account for the work done by the players (Soligard et al., 2016). Furthermore, research has reported that athletes may perform at a higher TL than what is indented by their coaches (Brink et al., 2014). Hence, monitoring both E-TL and I-TL load for each athlete can reveal patterns in the relationship between them, and thus help ensure that the applied load matches that prescribed by the coach (Soligard et al., 2016). Moreover, the E-TL can elicit different I-TL, making each individuals' training dose different. The difference may increase even further when taking into consideration that only 11 players can start each game. Abbott, Brickley, and Smeeton (2017) reported that games produced the greatest TL values. Hence, competitive game play may be the element that produces the greatest individual differences in gross TL throughout a cycle, as well as producing the greatest differences between starters and non-starters (Los Arcos et al., 2017; Martín-García, Diaz, Bradley, Morera, & Casamichana, 2018).

2.3.1 Internal training load

The use of heart rate monitoring has in many years been the most common measure for the I-TL in football (Alexandre et al., 2012). It has provided a non-invasive measure of the physiological function of the players. However, the movement patterns in football are characterized by intermittent activities such as sprints, jumps, high-intensity running, duels, tackles, change of directions, walking and standing still (Alexandre et al., 2012). Thus, presenting the mean heart rate during football play may underestimate the I-TL elicited on the players, with factors such as adrenaline playing a particular role during match play (Alexandre et al., 2012). Moreover, research has reported that football players today require a greater anaerobic capacity than before (Di Salvo et al., 2007; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013a).

A new approach began when Foster et al. (2001) introduced the sRPE CR10- scale, where each player grades their perceived exertion from 0-10 (whereas 0 being rest and 10 being maximal) and then multiplying their RPE with the duration of the exercise to get an arbitrary unit of the players' I-TL; sRPE. The sRPE has been reported to be a good indicator for I-TL and to include factors such as physical work rate, injury, illness, match scheduling and day-to-day variation in the players' physiological status (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Moreover, associations between sRPE and TDC and accelerometer derived variables have been observed (Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013). It should be mentioned that the duration is an E-TL measure, and thus sRPE becomes a mixture of both TL categories.

2.3.2 External training load

E-TL can be measured by time-motion analyses, e.g. video recordings, which is still often used during match play (Akenhead & Nassis, 2016; Di Salvo et al., 2007). It made it possible to calculate distances and speed by applying a coordinate system on the pitch. However, the post-analyze is time consuming when compared to global positioning system (GPS) technology, which can be monitored in real time (Scott, Scott, & Kelly, 2016). GPS made more variables easily available to analyze, and thus gave rise to a more detailed planning of the E-TL, as well as providing a greater insight to the physical match play demands in sports (Scott et al., 2016). The use of time-motion analysis (e.g. GPS) provides accurate information about TDC, TDC per minute ($TDC \cdot min^{-1}$) and distance in different speed categories, as well as peak speed (Malone, Lovell, Varley, & Coutts, 2017; Soligard et al., 2016). Another example of an E-TL is movement frequency counts (e.g. number of shots, jumps and tackles), which is difficult to capture using GPS devices (Soligard et al., 2016).

In recent years, further technological developments have been implemented in the GPS devices, such as triaxial accelerometers. Thus, it can quantify the sum of all forces acting on an athlete, and impact measures by reporting data on player contact and collisions with other players (Scott et al., 2016). These methods are commercially known as player/body load, depending on the different companies' specific algorithms (Malone et al., 2017). The triaxial accelerometer may also be divided into each specific axis, as well as only removing the vertical component. The removal of the vertical component can be of interest in team sports such as football because running affects the vertical component in a significant manner, and therefore, be able to focus on the two other components; anteroposterior and mediolateral (Malone et al., 2017). Furthermore, the implementation has expanded further with magnetometers and gyroscopes, which may provide greater knowledge about sport specific movements and load patterns, decelerations, accelerations and change of directions (defined as high intensity efforts), which has been documented in international women's team handball (Luteberget & Spencer, 2017). This may also be of interest when investigating the position-specific demands in a competitive environment in football.

2.3.3 The relationship between internal and external TL

Both acute and chronic training adaptions are the result of the accumulated I-TL over a given time period, and thus, there should be a relationship between the different E-TL variables and the I-TL elicited (McLaren et al., 2018). Enhanced knowledge of the internal-external TL (I-TL – E-TL) relationship has the potential to further enhance training periodization, as well as provide evidence for the validity and sensitivity for specific I-TL measurements (McLaren et al., 2018). For practical applications, an enhanced knowledge of the individual I-TL response to various E-TL has the potential to augment periodization. Coaches and sport scientists should select tools to monitor both TLs, as it can provide information on TL adaptation for each player (Bourdon et al., 2017).

One out of many adaptions in regard to endurance training is the ability to perform a greater external work to the relatively same internal response (Impellizzeri, Marcora, & Coutts, 2019). Therefore, a ratio between the more practically accessible measure of RPE and external work elicited, could potentially indicate whether this statement is true or not; a similar internal response to a progressively increased external work over a sufficient amount of time, may indicate a possible better physical conditioning. Oppositely, a progressively higher internal response to the same external work, may inform coaches, players and practitioners about possible abnormalities or a decrease in physical conditioning.

A meta-analysis by McLaren et al. (2018) reported a relationship with sRPE and TDC to be possibly very large, and likely large with accelerometer-derived load variables. The relationship between sRPE and high-speed running distance was reported to be likely moderate. Moreover, the relationship between very high-speed running distance and sRPE was unclear (McLaren et al., 2018). However, results from Owen, Lago-Peñas, Gómez, Mendes, and Dellal (2017) showed that players reported higher sRPE values when they performed a greater distance in high-speed running, and thus a relationship between sRPE and running speed might be indicated. With RPE as the dependent factor, relationships were reported to be extremely large for TDC, very large for high-speed running distance and moderate for accelerometer derived load and very high-speed running distance (McLaren et al., 2018). The decreased relationship with speed and RPE when increasing the speed may be explained by a greater measurement error of GPS devices at high velocities (Rampinini et al., 2015), as well as the lack of individualized speed thresholds and the personal association between running speed and internal exercise intensity (McLaren et al., 2018). Hence, the relationships are not perfect, meaning that there are other factors influencing their reported I-TL. Also, the I-TL – E-TL relationship may change during the competition phase as well, due to factors such as match importance (Link & de Lorenzo, 2016).

2.3.4 Current practice and implications for TL monitoring in football

Besides monitoring of TL in professional football, it is also common to assess discrete physiological, physical and biological responses to TL. The biological and physiological assessments may be blood samples, saliva analysis and creatine phosphate recovery analysis. Moreover, it is common to monitor autonomic nervous system function using heart-rate indices, while the physical assessments may be a variety of maximal of submaximal performance measures and subjective self-report measures (Akenhead & Nassis, 2016).

A recent study conducted by Akenhead and Nassis (2016) reported that 40 out of 41 football clubs collected individual data derived from GPS during every training session, whereas the remaining club objectively quantified E-TL on a subgroup of the players due to limited equipment and economic reasons. Furthermore, variables relating to acceleration activity and distance covered above absolute speed thresholds (e.g. high-speed running and sprint running) were reported to be the most common output variables. Moreover, all 41 participating clubs reported over 50 different variables that were monitored. The huge span of variables may be reflective on of the recent emerge of many, and a lack of empirical support for their validity, reliability and usefulness (Akenhead & Nassis, 2016). Interestingly, each practitioner recorded 7 ± 2 (range 4-10) TL variables during training sessions and 3 ± 2 TL (range 0-7), variables during competition. Moreover, four of the top-10 variables used to quantify TL during training could not be monitored during competition (Akenhead & Nassis, 2016). The differences may likely be due to the restrictions from FIFA regarding the use of wearable microsensor technology at the time of data collection.

With a limited amount of resources, the use of sRPE is an inexpensive method which can quantify their internal response produced during the whole training session/competition. It is therefore interesting that Akenhead & Nassis (2016) reported that HR monitoring was widely accepted as a tool for monitoring I-TL during training sessions. In regard to reports from Alexandre et al. (2012) regarding inaccuracy in HR monitoring in football, it was surprising to see that the use of RPE was less common (Akenhead & Nassis, 2016).

Lastly, there seems to be a lack of individualized thresholds in high-level football due to the FIFA restrictions on the use of microtechnology during competition, which in turn increases the cost:benefit ratio of implementing individualized thresholds during training alone (Akenhead & Nassis, 2016). The use of generic speed thresholds restricts interpretation of individual physiological demands, and there is no consensus on how to appropriately establish individual limits from which to express relative intensities for linear running (Akenhead et al., 2016). The possession of individual mechanical and metabolic running abilities creates a specific peak speed and a specific “speed-profile”. The use of a speed-profile with generic speed thresholds that is based on a “one size fits all”, may underestimate the physiological workload of individuals. For instance, the measure of distance covered above a certain speed threshold may impose a greater physiological stress on a slower player compared to a faster player (Casamichana, Morencos, Romero-Moraleda, & Gabbett, 2018).

2.4 Training load in match play

Research has reported football players to have a TDC of 10-12 kilometers during match play (Di Salvo et al., 2007). Approximately 30% of the distance is covered in high-speed running (>19 km/h) and the remaining 70% is covered by low-intense actions (Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010). A small increase in TDC (2%) over 7 seasons in the English Premier League has been reported (Barnes, Archer, Hogg, Bush, & Bradley, 2014). Although the small increase in TDC, there seems to be a match load with greater explosive demands for the players, as they are exposed to a 30% and a 35% greater high-intensity running distance and sprint distance, respectively (Barnes et al., 2014). Moreover, each playing position possesses different match demands, with full backs, central midfielders and wide midfielders covering the greatest distance. A possible explanation may be due to their role of being a link between the attacking and defending phases of the game (Bush et al., 2015). There has also been a greater contribution of high intensity running and sprint distance for all positions (Bush et al., 2015).

Although minor differences in TDC between positions has been reported, the difference in position specific physical demands come clear when assessing the distance covered in different velocity categories (Di Salvo et al., 2007). Overall, central defenders cover less distance in sprint and high intensity running than wide defenders and wide midfielders, likely due to a more open space at the wide areas of the pitch (Bush et al., 2015). However, distance per minute and average distance is greater for central midfielders. Thus, midfielders work-rate is more continuous, possibly due to their connection between defenders and attackers and a tighter space around them, while the wide players is exposed to short bouts of high-intensity explosive efforts and longer sprint distances (Di Salvo et al., 2007). This is supported by modern research with the use of GPS technology (Abbott et al., 2017; Malone et al., 2015), showing the same pattern.

2.5 Training load throughout the competition phase in football

During the competition phase, it is not common to increase physical fitness of the football players, and instead the focus is on technical/tactical enhancement and simultaneously maintain the physical capacities developed during preseason (Brink et al., 2014; Reilly, 2007). For instance, Malone et al. (2015) reported a mean TDC during preseason to be ≈ 7500m, compared to ≈ 5000m throughout the competition phase. Furthermore, a specific periodization theory to football needs for more research, mostly due to each clubs' unique coaching strategies (Owen et al., 2017)

2.5.1 Between mesocycles and between microcycles

Differences in TL between mesocycles and between microcycles in the competitive phase of the season has been reported to be minor (Gaudino et al., 2013; Malone et al., 2015; Oliveira et al., 2019; Owen et al., 2017). The findings emphasize the theory that the focus in the competitive phase lies on developing tactical and technical abilities, while the physical capacity is maintained to ensure optimal development of the aforementioned abilities (Reilly, 2007). The accumulated TL within microcycles has shown to be 2-4 times greater than match load demands for PlayerLoad™ (PL™), TDC, high-speed running distance and sprint distance, depending on the variable and the number of training sessions within microcycles (Clemente et al., 2019). Moreover, Malone et al. (2015) suggest that the training programs for elite football teams remains constant in the competitive phase due to the need to win matches that does not allow the reaching of a specific peak for strength and conditioning. The importance of each match is directly the same throughout the season, but it becomes much more clear at the late phases of the season, which may cause different TL outcomes (Link & de Lorenzo, 2016).

Malone et al. (2015) divided the competitive phase into six 6-week mesocycle blocks to examine potential differences in TL variables across the season. Differences in TDC were solely present when comparing the first to the last with a mean difference of 1304 m. Moreover, significant differences were found in %HRmax, with the third mesocycle eliciting a mean 3.3% greater value compared to the first mesocycle. To investigate potential differences further, the researchers reported a greater TL in the first microcycle of the competitive phase compared to the mid-season microcycle and the last microcycle of the season. it is suggested that the higher values in the first mesocycle is a result of the coaches' still having some emphasis on physical conditioning originating from preseason. Despite the difference in TDC in the first mesocycle, all other mesocycles were monotonous, which is similar to results reported by Owen et al. (2017), which reported no inter-variance in TL across a 6 week in-season mesocycle. Also, similar findings were reported by Gaudino et al. (2013) during a 10-microcycle period in the English Premier League, and supports the theory that the main focus in-season is development of technical and tactical skills as well as a maintenance of the physical capacities developed during pre-season (Malone et al., 2015).

More recent research investigated potential differences in TL throughout the competitive phase of the Portuguese league, divided into 10x4-week mesocycles. Results indicated minor differences throughout the competition phase, a greater TDC was observed in the first and third mesocycle (mean 1044m and 1146m, respectively) compared to the last mesocycle, with a tendency to decrease towards the end of the season (Oliveira et al., 2019). This is further support of the theory that coaches still have some emphasis on physical conditioning in the start of the competitive phase, suggested by Malone et al. (2015). Moreover, they reported a steady decrement of TDC throughout the competition phase. Even though, as mesocycle 10 only produced the lowest values for $TDC \cdot min^{-1}$, mesocycle 5 elicited the lowest values for TDC and high-speed running distance (mesocycle 1 produced the greatest values). The researchers state that the lower values elicited mid-season may be due to the Christmas schedule with a closer match program, hence reduced frequency of training sessions and either reduced intensity and/or duration of each training session (Oliveira et al., 2019).

When comparing the weekly mean values for TDC in each mesocycle and microcycle for the aforementioned research, the values range from 3722m (Gaudino et al., 2013) to 6871m (Owen et al., 2017), which indicates different physical demands in different professional football leagues as well as individual coach-dependent load strategies. Furthermore, unlike speed thresholds for each research paper and the number of variables available for export highlights the methodological variation in which there is no consensus, and thus emphasizes the struggle to compare (Akenhead & Nassis, 2016; Oliveira et al., 2019). To my knowledge, no research has reported differences in TL derived from triaxial accelerometers throughout the competition phase.

Few studies have reported the difference in I-TL throughout the competition phase, and more research is needed. However, Oliveira et al. (2019) reported a mean sRPE value throughout the competition phase of 254.8 AU, with mesocycle 1 eliciting the greatest value and mesocycle 5 producing the lowest value. The greater sRPE value was mainly due to a longer duration of the training sessions in this mesocycle compared to the other, and the lower values found in mesocycle 5 is mainly due to a greater number of matches (thus, fewer training sessions and decreased TL in each training session). However, the mean value is lower than what was reported by Scott et al. (2013a), as well as the reported values from (Casamichana et al., 2013). In regard to %HRmax, the I-TL reported by Malone et al. (2015) was significantly lower than what was found in semi-professional footballers (Casamichana et al., 2013) and in Korean footballers (Jeong, Reilly, Morton, Bae, & Drust, 2011). Moreover, the Korean football players elicited a significant greater sRPE and RPE value in a microcycle during pre-season compared to a microcycle in the competition phase, underlining previous discussed matters regarding physical maintenance. More research is needed to understand how the internal response alternates throughout the competition phase of the season.

Interestingly, a recent research paper regarding TL from a Norwegian premier league club collected accumulated and average weekly high-speed running distance (>19.8 $km \cdot h^{-1}$) and sprint distance (>25.2 $km \cdot h^{-1}$), as well as accelerations and decelerations in a microcycle. Data were collected throughout the 2018 season in microcycles containing 1 game and 4 training sessions (Baptista, Johansen, Figueiredo, Rebelo, & Pettersen, 2019). The accumulated mean values relative to match play for all positions were 57-71% and 36-61% for high-speed running distance and sprint distance, respectively. Conversely, accumulated accelerations and decelerations within microcycles tended to exceed match load demands, emphasizing an excessive usage of small-sided games (SSG) in training sessions, which is also predominantly observed in other studies (Clemente et al., 2019). The researchers further discuss that there should be a difference between TL in microcycles and match load, given that simply reproducing match demands in training sessions would oversimplify the complex process of developing players. Thus, the concept of "train as you play" is highly impractical due to high match load demands and the associated injury risk (Baptista et al., 2019).

2.5.2 In-week periodization

One of the major aims for training sessions in the competition phase is to prepare the players both technically, tactically, psychologically and physically for match play. The weekly periodization in professional football reports different E-TL and I-TL in each training session and are usually expressed in relation to the number of days until match day (Abbott et al., 2017; Malone et al., 2015; Owen et al., 2017). Additionally, with in-season microcycles have a duration of 3-7 days, it is suggested a “multiple peaking” periodization model is required in order for players to repeatedly perform at a high level in all matches across the season (Akenhead et al., 2016). To achieve the optimal readiness for competition, coaches can alter the pitch size, game formats, the duration of each training game, and simultaneously stimulate match specific demands. Contrary to the findings in chapter 2.5.1, research regarding differences in TL variables within microcycles suggest clear tapering strategies to unload the players aiming to increase the readiness and reduce the accumulation of fatigue preceding competitive match play (Akenhead et al., 2016; Anderson et al., 2016; Gaudino et al., 2013; Malone et al., 2015; Oliveira et al., 2019; Owen et al., 2017; Stevens, de Ruiter, Twisk, Savelsbergh, & Beek, 2017). However, the strategies are not in a uniform format, which highlights the coach-dependent approaches in different clubs.

It has been reported that TL declines across a training microcycle, and findings from the studies indicate the same trend within microcycles; higher TL occur in the beginning or in the middle of the microcycle followed by a reduction of TL as MD gets closer. Furthermore, MD elicits the greatest TL for all variables in all research papers. By expressing training sessions in relation to the number of days until MD, a consensus in all studies up to date is that MD-1 elicits significantly lower total TL in all variables (both E-TL and I-TL) compared to the other training sessions within microcycles. Malone et al. (2015) proposes the decrease to be an attempt by coaches to unload the players the day preceding a competitive match in order to increase player readiness. However, when excluding MD-1, TL differences within microcycles is highly monotonous with no significant differences between the other training sessions (Malone et al., 2015). The findings are contrary to the statement made by Brink et al. (2014), suggesting that TL must be varied to elicit optimal physiological adaptions and limit the negative effects of fatigue.

Also contrary to the findings reported by Malone et al. (2015), other studies have reported either linear or non-linear tapering strategies within microcycles. Owen et al. (2017) reported a tapering strategy with significant TL differences in all variables analyzed across the microcycle, with MD-3 (training session 2) eliciting the greatest values for TDC, high-speed running distance, sprint distance and sRPE. Similar findings were reported by Akenhead et al. (2016), which also reported a non-linear tapering strategy for the triaxial accelerometer derived PL™ variable. Moreover, clear evidence for periodization and tapering towards MD were reported by Anderson et al. (2016). Interestingly, Owen et al. (2017) reported greater values for TDC·min^{-1} despite a lower sRPE load on MD-2, which may be a coach strategy to reduce the effects of accumulative fatigue based on the previous day. This further highlights the complexity of tapering models based on numerous variables and numerous tactical approaches. Furthermore, it becomes even more complex when taking into consideration that there is not a uniform way set speed thresholds, and that the accelerometer derived TL variables has different formulas in which they calculate TL values.

Instead of expressing TL values in absolute figures, Stevens et al. (2017) expressed TL elicited in training session as percentage of match load. The researchers further suggest that this relative expression can be very valuable, since it facilitates the interpretation of the data, and hence the training prescription as well as the communication between practitioners, coaches and players. Furthermore, findings from this study showed a mean TDC of 5614 m (range 35-67% of match load) and a mean high-speed running distance of 203 m (15-38% of match load) within microcycles. Moreover, another study examining TL relative to match load on a microcycle level presented the greatest values for TDC on MD-3 (mean 57% of match load), and the greatest high-speed running distance (37% of match load) and sprint distance (45% of match load) at MD-4 (Martín-García et al., 2018). The researchers further observed large variations between the same training sessions in different weeks, which highlight the coaches' ability to adjust training content in relation to physical recovery and conditioning requirements for that week. When expressing the tapering pattern throughout a microcycle, a linear decrease was observed (Martín-García et al., 2018; Stevens et al., 2017), which is in line with recent research that reported a linear decrease in E-TL throughout the microcycle (Oliveira et al., 2019). Moreover, Martín-García et al. (2018) contextualized the training content throughout a microcycle in relation to the stimulated TL in the corresponding training session. The great TL in MD-4 was likely due to intense SSGs, while the lesser TL in MD-2 and MD-1 was related to a greater time focusing on tactical approaches to match play (e.g. set pieces) in the training session.

The differences in TL in a microcycle may also depend on the different training games each training session contains. Abbott et al. (2017) reported that large-sized games, medium-sized games and SSGs to stimulate different physical capacities. Large-sided games produced the highest average TDC intensities, and lowest in SSGs. Very high-speed running and sprinting distances increased with game format, and may be due to a larger absolute playing areas, thus enough space to reach high-speeds unopposed (Abbott et al., 2017). The average moderate-intensity explosive distances (accelerations and decelerations between 2 and 3 m/s^2) were highest in SSGs and decreased as the game format increased. The I-TL was reported to be greatest in SSGs, and decreased as the game format increased (Abbott et al., 2017). SSGs is often incorporated in the training regime due to its effective way to stimulate football specific movement patterns, match intensity and technical challenges under fatigue (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Interestingly, results from Abbott et al. (2017) suggested no training game format developed overall football fitness, with each format eliciting a unique physical load. Additionally, Abbott et al. (2017) further emphasized that different pitch sizes should maintain a match specific relative pitch area per player to maintain physical TL transferability to match play.

2.6 Seasonal training load quantification in other intermittent team sports

Team sports naturally played in an indoor environment (e.g. futsal and basketball) have obvious limitations to the use of global navigation satellite systems (GNSS) and research has mainly reported accumulated weekly TLs derived from sRPE, as well as presenting the intensity distribution of training sessions in different intensity zones. However, recently developed time-motion analysis equipment with the use of local positioning systems can give insight in a greater number of E-TL variables in indoor sports (Luteberget, Spencer, & Gilgien, 2018).

In futsal, the use of sRPE and physiological markers showed significant greater mean weekly TL in pre-season compared to in-season, likely due to a decrease in training sessions and increase in matches. Moreover, greater sRPE values were present in the 2nd mesocycle compared to the other. The augmentation in sRPE were likely an approach by the coach to stimulate match load in training sessions due to a decreased number of matches in that period, similar to preseason (Miloski, de Freitas, Nakamura, de A Nogueira, & Bara-Filho, 2016). Moreover, male college basketball players seem to have a high week to week variation in TL with several spikes (peak week of 226%) in TL throughout the competition phase (Conte, Kolb, Scanlan, & Santolamazza, 2018). The week to week differences were also prominent in female basketball players competing in the Lithuanian league, but with lesser magnitude (Paulauskas et al., 2019). These findings are in line with results derived from Manzi et al. (2010) who reported significantly greater weekly TLs in microcycles in which no games occurred, compared to 1-game microcycles and 2-game microcycles. Furthermore, the research reported by (Manzi et al., 2010) showed an exponential precompetitive tapering strategy 1-game microcycles.

Studies regarding Australian football have also mainly focused on TL originated from RPE and sRPE (Juhari et al., 2018; Moreira et al., 2015; Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2016). Commonly, all studies reported decreased TLs in-season compared to preseason and no further differences during in-season phase. Contrary, the results reported by Ritchie et al. (2016), indicated increased high-intensity running distance (>14.4 $km \cdot h^{-1}$) and PL™ in the 3rd mesocycle compared to the 1st and 4th mesocycle. In research regarding Rugby, TL provoked in the preseason seems to be greater compared to in-season, and no further differences in the in-season phase (Cross, Williams, Trewartha, Kemp, & Stokes, 2016; Phibbs et al., 2017).

2.7 Summary

The main goal in periodization is to achieve the greatest physiological capacity as possible and maximize the readiness prior to competition. The periodization of training can be altered by adjusting the duration, frequency and intensity, as well as the recovery time between each training session. In theory, an “overloading” of players followed a gradual unloading (known as tapering) as well as sufficient recovery will eventually lead to a concept known as supercompensation. To achieve supercompensation in football, a proper periodization strategy is necessary due to the nature of the game and a saturated match program within a season. To achieve optimal periodization, the monitoring of TL in football has risen accordingly with the extended availability of monitoring methods available.

There are today many ways to monitor TLs and the current practice includes time-motion analysis and internal responses to the E-TL, and more recently, TL derived from triaxial accelerometers. However, practitioners between clubs have a huge variety in variables used to monitor TL, underlining the recent emerge of many and a lack of empirical support for their validity, reliability and usefulness. Nonetheless, the many methods have given rise to the well documented match demands in the literature.

There is evidence that TL decreases in the competition phase compared to the pre-season phase due to the augmented focus on technical and tactical abilities along with a greater match load. Contrary, research indicates that there are little or no differences in TL throughout the competition phase, suggesting that the need to win matches exceeds the reaching of specific peak for strength and conditioning. However, within each week of the competitive phase, clear differences between training sessions is evident, and studies show clear tapering strategies preceding match play aiming to increase the readiness and reduce the accumulation of fatigue preceding competitive match play. The same patterns seem to be evident in other intermittent team sports as well, throughout the competition phase and on a microcycle level.

3. Method

3.1 Study design and experimental approach

This master thesis was an observational study. Both E-TL and I-TL variables measured during match play and in training sessions were collected. The research was conducted throughout the 2018 competitive season (starting at game week 3; GW), from March 29th to December 2nd.

3.2 Subjects

A professional male football team from the Norwegian elite division was recruited to participate in the study (n=23, age; mean ± standard deviation (SD) = 26 ± 4 years). All players competed in the Norwegian premier league, and data was collected throughout the competitive season in both match play and training sessions. Training sessions on MD-1 was excluded due to previous findings regarding TL quantification on this training session (see chapter 2.5.2). However, training sessions on MD-4, MD-3 and MD-2 were included. The weekly training schedule and the days included in the study are shown in figure 3.1. The players wore devices during all matches and training sessions throughout the competition phase of the season. The Norwegian premier league is a professional league consisting of 16 teams, with all teams facing each other both home and away. Simultaneously, the Norwegian cup is ongoing throughout the season, and thus potentially ending the competition phase one week after the final league GW. The subjects were divided into groups corresponding to their role in the team; Defenders (DF; n=9), Midfielders (MF; n=10) and attackers (AT; n=4).

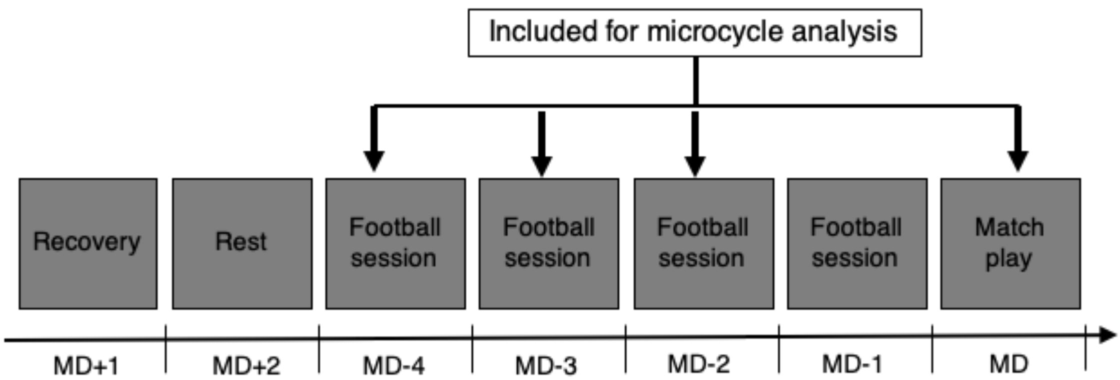

Figure 3.1: *A microcycle for the team observed, expressed as days in proximity to match play. Arrows shows the days in which data were collected and included in the study. Abbreviations: MD = Match day, +/- = Days in proximity to match play*

3.2.1 Inclusion criteria

Data was collected during each GW with a normal training cycle, which in this case would be defined as one game each microcycle. Hence, out of 31 GWs, 17 were included in the study. Moreover, data from 1 match and 2 training sessions were lost due to unknown errors in the software. Hence, eligible data for statistical analyses on external load consisted of 49 training sessions and 16 games.

Furthermore, all players included in the study had to have a minimum of 37 (75%) training sessions observed and simultaneously have observed data in at least 5 games. Thus, a total of 13 players were further excluded from the study. Additionally, goalkeepers were excluded from the study due to their unique role in the team and their significant difference in physical demands and TL patterns. Moreover, the inclusion criteria for horizontal dilution of precision (HDOP) and number of satellites (#SATS) were set to <2 and >4, respectively, which resulted in a further excluding of 1 observation. As a result, the study included a total of 10 players (Age=27 ± 3); 4 DF, 4 MF and 2 AT. For I-TL measures, all players (n=10) was included. However, observations from one particular player were lost due to reasons beyond the control of the researcher. In addition, I-TL markers from one training session were not registered. Lastly, I-TL markers on days in which observations on the external load was lost were excluded as well. Hence, I-TL variables were collected from 9 players; 4 DF, 3 MF and 2 ST. Total observations for E-TL and I-TL markers is presented in table 3.1 and table 3.2, respectively.

Table 3.1: *Number of observations on external load for included players in training and matches according to playing position, presented as total observations, mean and range (min-max). Abbreviations: O = Observations, min = minimum, max = maximum, DF = defenders, MF = midfielders, AT = attackers*

		O (n)	Mean	min	max
Training	All (n=10)	449	45	37	48
	DF (n=4)	185	46	45	47
	MF (n=4)	172	43	37	48
	AT (n=2)	92	46	46	47
Match	All (=10)	114	11	5	14
	DF (n=4)	49	12	11	14
	MF (n=4)	44	11	5	14
	AT (=2)	21	11	10	11
Match + Training		**563**	**56**	**42**	**61**

Table 3.2: *Number of observations for internal load markers when external load markers were observed, according to playing position. Data is presented as total observations, mean and range (min-max). Abbreviations: O = Observations, min = minimum, max = maximum, DF = defenders, MF = midfielders, AT = attackers*

		O (n)	Mean	min	max
Training	All (n=9)	386	43	36	46
	DF (n=4)	181	45	44	46
	MF (n=3)	117	39	36	41
	AT (n=2)	88	44	42	46
Match	All (=9)	89	10	9	17
	DF (n=4)	45	11	8	14
	MF (n=3)	25	8	5	12
	AT (=2)	19	10	8	11
Match + Training		**475**	**53**	**41**	**60**

3.3 Experimental procedures

To ensure minimal effect on performance, the experimental approach did not intervene with any aspects of the normal training, match and match preparation for both club and players. Additionally, the usage of the devices was already well incorporated in their daily training routine. Hence, a familiarization period beforehand was not completed. Extrinsic factors that could potentially influence their performance (e.g. nutrition, injuries etc.) were not controlled for and thus, the players prepared for each training session and match as they normally would. Each player used the same device throughout the commencement of the study to avoid high limits-of-agreement values, and thus avoid problems that arises from high interunit variability (Malone et al., 2017). This was ensured through a name tag on every device.

3.3.1 Data collection

The data collection was conducted on artificial turf at the football clubs' home arena for both training sessions and match play. However, the surface which the away game was played on varied depending on the opposition. The home turf was watered prior to each game and training session to secure optimal playing conditions. Due to restrictions regarding the use of real-time recordings during match play (IFAB, 2018), all data collection from match play was collected at the first training session observed after the game was played.

The data collection was conducted in cooperation with the clubs' fitness coach, which gave insight in their daily training program prior to each training session. The students then turned on the devices which contained GPS and a triaxial accelerometer (Catapult OptimEye X4, Queensland, Australia) and assigned each player with their corresponding device approximately 30 minutes prior to the training sessions. The players wore a custom-made vest from the manufacturer in which the device was placed in a pouch between the scapulae to ensure minimal movement of the device. In addition, it provided detection of movement without causing discomfort or affecting the players. In terms of accelerometer derived data, research has reported that the location of the devices results in higher values when it is placed on the center of mass (Barrett, Midgley, & Lovell, 2014). However, the placement on center of mass may alter the movement pattern (Barrett et al., 2016) and the signal from the GPS may be more interfered (Barrett et al., 2014).

15 minutes prior to the commencement of each training session, all players were on the pitch to secure proper GPS lock, as recommended by Malone et al., (2017). The training sessions were observed from courtside, simultaneously following signals in the Openfield software (version 1.18.0, Catapult sports, 2018). To obtain the information from the device, and additionally ensuring that all devices were turned on and functioning properly throughout the training session, the computer was connected to the wireless real-time receiver (minimax TRX; Catapult sports, Australia; Firmwire version 7.0.0.3). Separate periods were created in Openfield between each training drill in accordance with the insight given to the students prior to the training session. Furthermore, start and finish of each period as well as in-between breaks were recorded manually in a notebook to ensure that uncertainties and eventual errors could be double-checked and corrected after the training session if needed. The notebook also worked as an alternative in case the computer and/or the Openfield software did not function properly. During matches, the fitness coach was responsible for ensuring that the devices were turned on, were mounted correctly and had proper GPS lock.

The I-TL was collected through a commercial phone application (Athlete Monitoring, Moncton, Canada). Each player reported their RPE-score within 30 minutes after the training session was completed. The reported RPE-score was a modified Borg CR-10 scale suggested by Foster et al. (2001). Contrary to the collected E-TL data, the I-TL data was obtained by their fitness coach and further exported to the student after the intervention period.

When the training session was completed, the students collected the devices and placed them in a custom-made USB cradle (S5 Charge Case; Catapult Sports, Queensland, Australia) to begin the data import, cloud sync and data processing.

3.4 Catapult OptimEye X4 and external load measurements

Catapult OptimEye X4 is an electronic device which is approximately 96mm in height, 52mm in width, 14mm in thickness and a weight of 66.7 grams. It operates on the 2.4GHz Spectrum to send live data wirelessly to a real-time receiver and can therefore be used for measurement of movements and forces with immediate feedback (Catapult Sports, 2018b). The device contains a 10Hz GPS hardware engine, as well as an inertial movement unit which consists of a built-in 100Hz tri-axial accelerometer, a 2000 degrees·second^{-1} gyroscope, and a 100Hz magnetometer (Catapult Sports, 2018b). The device can therefore be used to monitor positional data and inertial movement data.

3.4.1 Global positioning system (GPS)

GPS originates from the US department of defense as a tool for navigation, marine and recreational outdoor purposes. Since the commercial release in 1997, its use has been widely applicated to monitor E-TL in team sports (Scott et al., 2016). It consists of 27 satellites spread across the earth, which is connected to a GPS receiver, and can be used to measure both position and speed. Briefly, the trigonometrical position is calculated by the signal travel time and the distance the signal travels with at least four satellites (Larsson, 2003). However, a receiver with less than 6 satellites connected tends to have a weaker connection (Malone et al., 2017). The speed in which the receiver is travelling can be determined by (i): Positional differentiation, which divides the cumulative distance between two points with the time spent, or (ii): Doppler shift, which is a measurement of the changes of the satellite signal frequency caused by the movement of the receiver (Larsson, 2003). Little information regarding how each manufacturer calculate speed is publicly available. However, Malone et al. (2017) reported Doppler shift to be the most common method through personal communication with the manufacturers. The accuracy of the GPS measurements is not solely determined by #SATS connected, but also HDOP, which is the placing of the of the satellites relative to each other and the receiver. Briefly, a higher HDOP value results in lower accuracy (Witte & Wilson, 2004). Disturbances in the signal from large buildings (i.e. football stadiums) can also have an effect on the accuracy (Scott et al., 2016).

3.4.2 Calculation of PlayerLoad™

PL™ is an accelerometer-based measurement of external physical loading of team sport athletes during training and match play (Luteberget & Spencer, 2017), and is supported in rugby union to monitor physical performance (Jones, West, Crewther, Cook, & Kilduff, 2015). It was originally developed together with the Australian Institute of Sport and is defined as "*a measure of instantaneous rate of change of acceleration divided by a scaling factor*" (Catapult Sports, 2017, 2018a). The scaling factor is used to ease the interpretation of the arbitrary unit it produces (Catapult Sports, 2017). PL™ "is expressed as the square root of the sum of the squared instantaneous rate of change in acceleration for each of the three vectors (*x, y,* and *z* axes) and divided by 100" (Boyd, Ball, & Aughey, 2011). The unit it produces can therefore be a measure of both intensity (in a given time or period) and accumulated TL (Catapult Sports, 2018a). The triaxial accelerometer may also be divided into each specific axis, as well as only removing the vertical component. The removal of the vertical accelerometer can be of interest for athletes covering short distances or have a small relative pitch area due to the effects of heel-strike during locomotion (Catapult Sports, 2018a; Malone et al., 2017). The equation for PL™ is described as follows:

$$PlayerLoad^{\text{TM}} = \sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

a_y = forward acceleration
a_x = sideways acceleration
a_z = vertical acceleration

3.4.3 Validity of the Catapult devices – positional and accelerometer data

To the authors knowledge, Catapult OptimEye X4 is an upgrade from the former device MiniMaxX S4 (Catapult Sports, Australia), with the only difference being that it is 40% lighter in weight and minor changes in exterior for better usability. Hence, studies regarding validity and reliability for GPS derived measurements will only include the same manufacturer, the same sampling rate (10Hz) and GPS compatible only (incompatible with other GNSS).

A study conducted on 10Hz GPS by Rampinini et al. (2015) reported findings of a good coefficient of variation (CV) for total distance (CV=1.9%) and high-speed running speed > 4.17 $m \cdot s^{-1}$ (CV=4.7%). Furthermore, the same study reported a poor CV (10.5%) for very high-speed running speed > 5.56 $m \cdot s^{-1}$, suggesting a weaker validity when the speed is augmented. Moreover, valid measurements were also found for 10Hz devices when tested on a team sport simulation circuit, with <1% error on total distance (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014). Furthermore, Castellano, Casamichana, Calleja-Gonzalez, Roman, and Ostojic (2011) reported a good-moderate standard error of measurement (SEM) on total distance of 3.8-9.6% (mean: 10.9%) for 15-m sprints and 1.7-6.7% (mean: 5.1%) on 30-m sprints using 10Hz devices. For instantaneous speed, Akenhead, French, Thompson, and Hayes (2014) reported a standard error of estimate of 0.12-0.32 m·s^{-1}, suggesting a reduced accuracy for accelerations > 4 m·s^{-1}.

For accelerometer derived data, Polglaze, Dawson, Hiscock, and Peeling (2015) and Gallo, Cormack, Gabbett, Williams, and Lorenzen (2015) reported a strong (r = 0.868) and nearly perfect (r = 0.97) coefficient of correlation between total distance and accumulated PlayerLoad™ in field hockey and Australian football, respectively. Furthermore, PlayerLoad™·min^{-1} has been reported to be a valid measure for intensity for Australian football (Mooney, Cormack, O'Brien B, Morgan, & McGuigan, 2013), and a moderate relationship (r = 0.49) between PlayerLoad·min^{-1} and distance·min^{-1} in field hockey has been reported (Polglaze et al., 2015). For internal load relationships, a meta-analysis conducted by McLaren et al. (2018) proved an unclear relationship between PlayerLoad™ and RPE, a likely large relationship between PlayerLoad™ and sRPE. Furthermore, between-subject relationships between PlayerLoad™ and VO_2 and heart rate during treadmill running has been reported as trivial to moderate (r = -0.43 and 0.33, respectively). Additionally, a nearly perfect within-subject relationship (r= 0.92-0.98, respectively) were also reported (Barrett et al., 2014).

3.4.4 Reliability of the Catapult devices – positional and accelerometer data

For positional data, Johnston et al. (2014) reported a good to poor interunit reliability of 10Hz GPS devices (typical error of measurement; TEM: 1.3-11.5%, Intraclass Correlation Coefficient; ICC: 0.51-0.97). The authors conclude that the interunit reliability decreases with increased speed. However, when measuring peak speed, a good interunit were reported (TEM: 1.64%, ICC: 0.97). Furthermore, Akenhead et al. (2014) reported good-moderate interunit reliability (CV=0.7-9.1%). Finally, both interunit reliability (CV= 1.3 and 0.7%) and intra-unit reliability (CV= < 4 and < 3%) were good for total distance on 15m and 30m sprints, respectively (Castellano et al., 2011).

For accelerometer derived data, the study conducted by Barrett et al. (2014) reported a moderate to high test-retest reliability of PlayerLoad™ during treadmill running (CV= 5.9%, ICC= 0.80-0.93). Moreover, within-device reliability has been reported by Boyd et al. (2011) as acceptable in a hydraulic shaker (CV= 1.01% for static-, and 0.91% and

1.05% for dynamic reliability, 0.5 g and 3.0 g, respectively). Furthermore, the same study reported that the devices have a good inter-unit reliability of 1.94% CV during nine Australian football matches, and thus suggesting that accelerometers can detect changes in physical activity during Australian football (Boyd et al., 2011). Thus, PlayerLoad™ can be recommended as a measurement of E-TL exclusively, but moderate to large variations in absolute PlayerLoad™ values should be taken to consideration when comparing absolute data from different athletes (Barrett et al., 2014).

3.5 Rate of perceived exertion

Rate of perceived exertion is a modified scale originally invented by Borg (1970). Each player grades their perceived exertion of the entire training session between 0-10, whereas 0 being the lowest perceived exertion (Foster et al., 2001). RPE can subsequently be multiplied by the duration of the training session to get an arbitrary unit as a measurement of I-TL.

3.5.1 Validity of rate of perceived exertion

RPE has been showed as a valid indicator for I-TL, correlating with VO_2, heart rate, and blood lactate, and quantifying stress from tasks unable to be recorded by the devices used in this particular study (e.g. jumping, grappling, heading and tackles) (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009; Hill-Haas et al., 2011). Furthermore, sRPE has been proved as a valid indicator for I-TL caused on the players (Foster et al., 2001). Additionally, the sRPE method has been reported to be a valid method to quantify training loads in high-intensity, intermittent team sport (Scott, Black, Quinn, & Coutts, 2013b). Also, when comparing I-TL and E-TL, Scott et al. (2013a) proved a high coefficient of correlation between PlayerLoad™ and sRPE ($r=.84$). Further correlations between RPE and other indicators of I-TL have previously been discussed (chapter 2.3.1).

3.5.2 Reliability of rate of perceived exertion

As reliability indicates the reproducibility for a measurement, a poor reliability of RPE may reduce the ability to track changes in training loads for an athlete (Scott et al., 2013b). However, a poor level of reliability (31.9 CV, 0.66 ICC) were reported during 8-minute bouts of running, with improved reliability levels with increased intensity

(Scott et al., 2013b). Recently, Wiig, Andersen, Luteberget, and Spencer (2019) reported substantial effects on within-player, between-player as well as between-session variability in all E-TL variables. Furthermore, a reliability of sRPE of 23% CV (90% CI, 21% to 26%) was estimated due to a great individual variability when adjusting for the E-TL. The poor reliability is dependent on several factors, such as the crude CR-10 scale of RPE, between-session variability and different recovery status between players before sessions. In addition, the change of fitness status across the season, or the ability of the E-TL variable to explain the true TL elicited by the players can also affect the reliability of sRPE (Wiig et al., 2019). Nonetheless, the strongest correlations between sRPE and E-TL were reported on low intensity-threshold variables (e.g. TDC and PL™), thus suggesting them be the most preferable TL measures when a single E-TL measure is used to describe TL (Wiig et al., 2019). Moreover, it should be noted that the use of RPE should be used with caution on athletes who is not familiarized with the procedure, especially youth academy players (Bourdon et al., 2017).

3.6 Data processing, interpretation and analyses

Once the data was imported to the computer and synced with the cloud, as well as double checked with the logged clock times in the notebook, the raw files were organized into 60 seconds intervals and exported as a CSV file to Microsoft® Excel for Mac Office 365 (Version 16.23; Microsoft, Redmond, WA, USA). Afterwards, the students manually benched inactive players between periods as well as in-between each period to create “benched” files. This was accomplished by logging the in-between breaks during training sessions in the notebook. The benched files were also organized into 60 second intervals and exported as a CSV file to Microsoft® Excel. For matches, the students exported the RAW file from the Openfield software to Microsoft® Excel. Afterwards, the break between first and second halves and non-starters were benched. The match report on the clubs’ official web site were used to ensure when the non-starters were substituted with a starter. Variables that were exported for further analysis were TDC, distance·min^{-1} (TDC·min^{-1}), PL™, PlayerLoad·min^{-1} (PL™·min^{-1}), distance covered >20 km·h^{-1} (High-speed running distance: HSRD) and distance covered >25 km·h^{-1} (Sprint distance: SPRINT) . After securing that the Excel files had a uniform format, they were further exported to MATLAB (version R2019a; The Mathworks Inc., Natick, Massachusetts, United States) for analyses.

I-TL variables were delivered to the students by the fitness coach after the intervention period. The sheet was custom-made by Athlete Monitoring and included I-TL variables from both training sessions and match play. The GWs in which the students did not observe, and the players that were not eligible in the study were removed in Microsoft® Excel. The data were exported to MATLAB for further analyses. The exported variables were RPE, duration and the combined measurement of these; sRPE.

3.6.1 Data processing and interpretation

In MATLAB, the summarized TDC, PL™, HSRD, SPRINT and sRPE as well as the mean TDC·min^{-1} and PL™·min^{-1} for each subject on every training session were calculated. Values from each training sessions within a corresponding GW were then categorized, making 17 different GW folders containing one MD-4, one MD-3, one MD-2 and one MD folder for the variables. Furthermore, four folders with every subjects' TL value from every MD-4, MD-3, MD-2 and MD were categorized. RPE values were paired with their corresponding training sessions.

3.6.2 Analyses of the differences in training load on a microcycle level

In order to analyze full-team differences in TL on a microcycle level, individual means were calculated for all subjects' TL on MD-4, MD-3, MD-2 and MD. Further, the individual mean calculated for each subject on MD-4, MD-3 and MD-2 were calculated as a percentage of their individual mean on MD. Moreover, the individual means were used to calculate a full-team mean on MD-4, MD-3 and MD-2 on all training load variables, expressed as percentage of match play demands. This was chosen to provide a realistic representation of relative TL on a microcycle level due to the insufficient number of subjects available.

To analyze the full-team differences on a microcycle level for the I-TL – E-TL relationships, four different ratios (TDC/RPE, PL™/RPE, TDC/sRPE and PL™/sRPE) were made for every subject on every MD-4, MD-3, MD-2 and MD throughout the competition phase, and further categorized into the corresponding GW folders. In order to analyze positional differences on a microcycle level, each individual mean from all training sessions and match play for the corresponding positions were used to calculate a positional mean on each training session.

3.6.3 Analyses of the differences in training load throughout the competition phase

To analyze the potential differences and changes in load patterns throughout the season, all GWs was categorized into 6x5-GW mesocycles. However, because 31 is a prime number, the last mesocycle included four GWs. Moreover, for the mesocycle to be included in the analyses, at least three out of the five GWs had to be observed. Hence, a total of four mesocycles were included in the study (figure 3.2).

To analyze each mesocycle, the mean TL in all GWs in the corresponding mesocycle for each subject were used to calculate a meso-mean for each subject. The meso-mean for each subject were then expressed as percentage of mean individual match play demands. The calculated percentage for each subject were then used to calculate a full team mean for the corresponding mesocycle. To analyze the potential positional difference throughout the season, the meso-mean for each subject were used to calculate positional means.

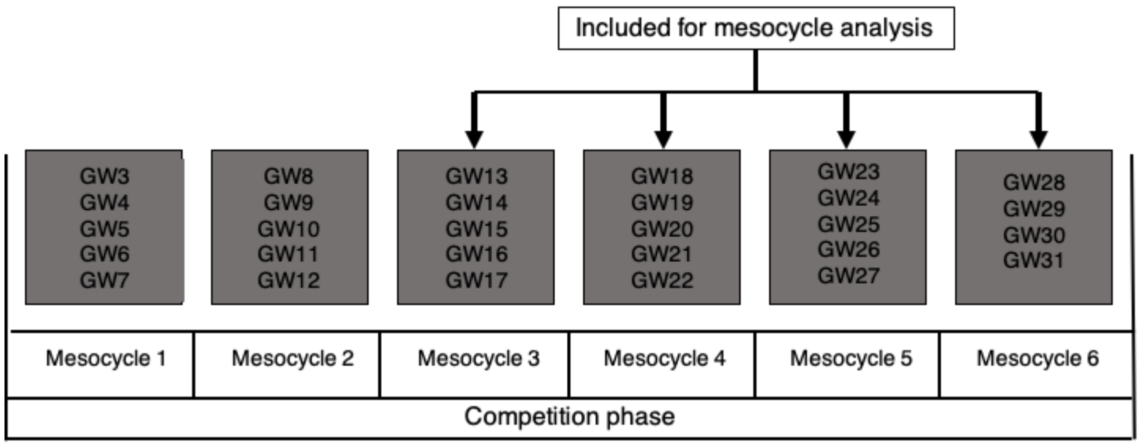

Figure 3.2: *The competitive phase from the beginning of the intervention, divided into six mesocycles with corresponding GWs in each mesocycle. Black arrows show the mesocycles in which data were included in the study. Abbreviations: GW = game week.*

3.7 Ethics

All players signed the letter of consent, which followed the recommendations of the Helsinki declaration, prior to the commencement of the study and were informed about the potential risks when participating. Furthermore, they were informed that they could withdraw from the study at any time without any further consequences nor explanation. The study was approved by the Norwegian Centre for Research Data and the Norwegian School of Sport Sciences' ethic committee. The personal information about the subjects were kept de-identified. Further, the scrambling key was stored in a safe according to the school's regulation for a minimum five years after the conclusion of the study for potential verifiability purposes. After, the scrambling key will be destroyed, and the subjects will be anonymous.

There are always potential injury risks when competing on a high level of football. However, the study did not intervene with any parts regarding their training session and match routines. Hence, no further risks beyond the normal regarding injuries, illness or other similar factors were elicited on the subjects. Additionally, to avoid potential conflict of interests between the study and the club, a non-disclosure agreement were signed to prevent sharing of tactical approaches to any opponents.

3.8 Statistical analyses

Results are presented as mean ± SD. Full-team and positional differences between training sessions within microcycles and between mesocycles were calculated by using a customized spreadsheet (Hopkins, 2017) in Microsoft® excel office 365 for Mac, version 16.34 (20020900). Analyzes were performed using Cohen´s effect size (ES) statistics and a confidence interval (CI) of ±90%. ESs were defined as <0.2 trivial, 0.2 to 0.6 small, 0.6 to 1.2 moderate, 1.2 to 2 large and >2.0 very large (Batterham & Hopkins, 2006; Hopkins, Marshall, Batterham, & Hanin, 2009). Magnitude based inferences (MBI) were used to describe probabilities of difference between training sessions on a microcycle level, between mesocycles and positional differences being substantially higher, trivial or lower than the comparison. They were considered almost certainly not (<0.5%), very unlikely (0.5-5%), unlikely (5-25%), possible (25-75%), likely (75-95%), very likely (95-99.5%) or most likely (>99.5%). A percentage likelihood of difference <75% was considered a substantial magnitude. Threshold chances of 5% for substantial magnitudes were used, meaning a likelihood of >5% in both a positive and negative direction was considered unclear (Batterham & Hopkins, 2006; Hopkins et al., 2009). No statistical analyses were performed solely on attackers due to an insufficient number of subjects.

4. Results

4.1 *In-week periodization throughout the competition phase*

4.1.1 Full-team differences in training load within microcycles

Full-team differences and statistical inferences within microcycles are shown in table 4.1 – 4.6. For distance-derived variables, the mean ± SD TL values produced were 4438 ± 852 m for TDC and 79.2 ± 8.5 m for TDC·min^{-1}. For both variables, MD provoked the greatest values, followed by MD-3, then MD-4, while MD-2 elicited the lowest values. MD-3 produced a 46.9 ± 9.1% greater TDC and a 22.7 ± 5.9% greater TDC·min^{-1} than MD-2 (Table 4.1).

Table 4.1: *Distance-derived TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC (m)					
MD	10669 ± 588	vs MD-2	13.9	100/0/0	Most likely
		vs MD-3	9.7	100/0/0	Most likely
		vs MD-4	11.7	100/0/0	Most likely
MD-2	3635 ± 283				
		vs MD-3	4.5	0/0/100	Most likely
		vs MD-4	2.0	0/0/100	Most likely
MD-3	5332 ± 395				
		vs MD-4	2.7	100/0/0	Most likely
MD-4	4347 ± 375				
TDC·min^{-1} (m)					
MD	110.9 ± 8.3	vs MD-2	5.5	100/0/0	Most likely
		vs MD-3	2.8	100/0/0	Most likely
		vs MD-4	4.4	100/0/0	Most likely
MD-2	72.3 ± 3.8				
		vs MD-3	3,1	0/0/100	Most likely
		vs MD-4	0.8	1/5/95	very likely
MD-3	88.7 ± 5.7				
		vs MD-4	1.9	100/0/0	Most likely
MD-4	76.6 ± 6.1				

For speed-derived variables, the mean values within microcycles were 175.1 ± 75.7 m for HSRD and 37.9 ± 25.8 m for SPRINT. For both variables, MD stimulated the greatest values, followed by MD-2, then MD-3, while MD-4 provoked the lowest values. Between training sessions, MD-2 and MD-3 elicited 182.0 ± 95.2% and 161.0 ± 78.3% greater HSRD compared to MD-4, respectively. Furthermore, MD-2 provoked the greatest SPRINT compared to the other training sessions (Table 4.2).

Table 4.2: *Speed-derived TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
HSRD (m)					
MD	703.7 ± 262.1	vs MD-2	2.3	100/0/0	most likely
		vs MD-3	2.3	100/0/0	most likely
		vs MD-4	3.0	100/0/0	most likely
MD-2	221.2 ± 60.3				
		vs MD-3	0.1	17/79/4	likely
		vs MD-4	2.4	100/0/0	most likely
MD-3	216.2 ± 86.4				
		vs MD-4	1.8	100/0/0	most likely
MD-4	87.8 ± 36.9				
Sprint (m)					
MD	183.30 ± 108.48	vs MD-2	1.4	99/1/0	very likely
		vs MD-3	1.6	99/0/0	very likely
		vs MD-4	2.1	100/0/0	most likely
MD-2	61.41 ± 17.53				
		vs MD-3	0.7	94/5/0	likely
		vs MD-4	3.4	100/0/0	very likely
MD-3	41.90 ± 29.65				
		vs MD-4	1.3	99/1/0	very likely
MD-4	10.38 ± 8.02				

Mean PL™ for all training sessions within microcycles were 470.9 ± 95.0 AU and the mean PL™·min^{-1} was 8.78 ± 0.97 AU. For PL™, MD provoked the greatest value, followed by MD-3, then MD-4, while the MD-2 elicited the lowest value. Between training sessions, MD-3 stimulated the greatest PL™, eliciting 50.2 ± 11.7% greater load than MD-2 and 8.94 ± 5.31% greater load than MD-4. Moreover, MD-4 caused a 37.9 ± 9.0% greater load compared to MD-2. For PL™·min^{-1}, no difference was observed between MD-3 and MD-4, eliciting the greatest values compared to MD-2 (21.8 ± 5.1% and 22.1 ± 5.0%, respectively; table 4.3).

Table 4.3: *Accelerometer derived TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
PL™ (AU)					
MD	991.5 ± 56.9	vs MD-2	12.9	100/0/0	most likely
		vs MD-3	7.34	100/0/0	most likely
		vs MD-4	8.95	100/0/0	most likely
MD-2	364.3 ± 26.5				
		vs MD-3	3.9	0/0/100	most likely
		vs MD-4	3.0	0/0/100	most likely
MD-3	546.7 ± 54.0				
		vs MD-4	0.9	99/1/0	very likely
MD-4	501.8 ± 42.1				
PL™·min^{-1} (AU)					
MD	10.30 ± 0.83	vs MD-2	3.4	100/0/0	most likely
		vs MD-3	1.1	99/1/0	very likely
		vs MD-4	1.1	100/0/0	most likely
MD-2	7.66 ± 0.59				
		vs MD-3	2.2	0/0/100	most likely
		vs MD-4	2.3	0/0/100	very likely
MD-3	9.33 ± 0.80				
		vs MD-4	0.0	1/95/4	very likely trivial
MD-4	9.35 ± 0.76				

For the I-TL derived variables, the mean RPE value for all days within microcycles were 5.31 ± 1.23 AU and 431.4 ± 129.3 AU for sRPE. For both variables, MD elicited the greatest values, followed by MD-4, then MD-3, while MD-2 displayed the lowest values. When comparing the MD-4 and MD-2, a 61.9 ± 14.2% greater intensity for RPE and an 88.1 ± 20.0% greater load for sRPE were observed (Table 4.4)

Table 4.4: *Internal-derived TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
RPE (AU)					
MD	8.47 ± 0.34	vs MD-2	13.3	100/0/0	most likely
		vs MD-3	8.2	100/0/0	most likely
		vs MD-4	4.8	100/0/0	most likely
MD-2	4.00 ± 0.27				
		vs MD-3	4.5	0/0/100	most likely
		vs MD-4	6.3	0/0/100	most likely
MD-3	5.48 ± 0.33				
		vs MD-4	2.5	0/0/100	most likely
MD-4	6.45 ± 0.42				
sRPE (AU)					
MD	823.6 ± 53.4	vs MD-2	11.9	100/0/0	most likely
		vs MD-3	7.2	100/0/0	most likely
		vs MD-4	5.6	100/0/0	most likely
MD-2	287.5 ± 21.7				
		vs MD-3	5.9	0/0/100	most likely
		vs MD-4	7.3	0/0/100	most likely
MD-3	468.8 ± 32.6				
		vs MD-4	1.8	0/1/99	very likely
MD-4	537.9 ± 38.4				

Differences in TL variables and statistical inferences relative to match play demands are shown in figure 4.1. In regard to load variables, MD-2 elicited the lowest values for TDC, PL™ and sRPE, while at the same time producing the greatest values within microcycles for SPRINT. MD-3 provoked the greatest values for PL™ and TDC, and MD-4 caused the highest values for sRPE. No difference was observed between MD-3 and MD-2 for HSRD relative to match play. In regard to intensity variables relative to match play, MD-2 produced the lowest values for all variables. MD-3 elicited the greatest TDC·min^{-1}, while MD-4 stimulated the greatest RPE values. No difference was observed between MD-4 and MD-3 for PL™·min^{-1} relative to match play.

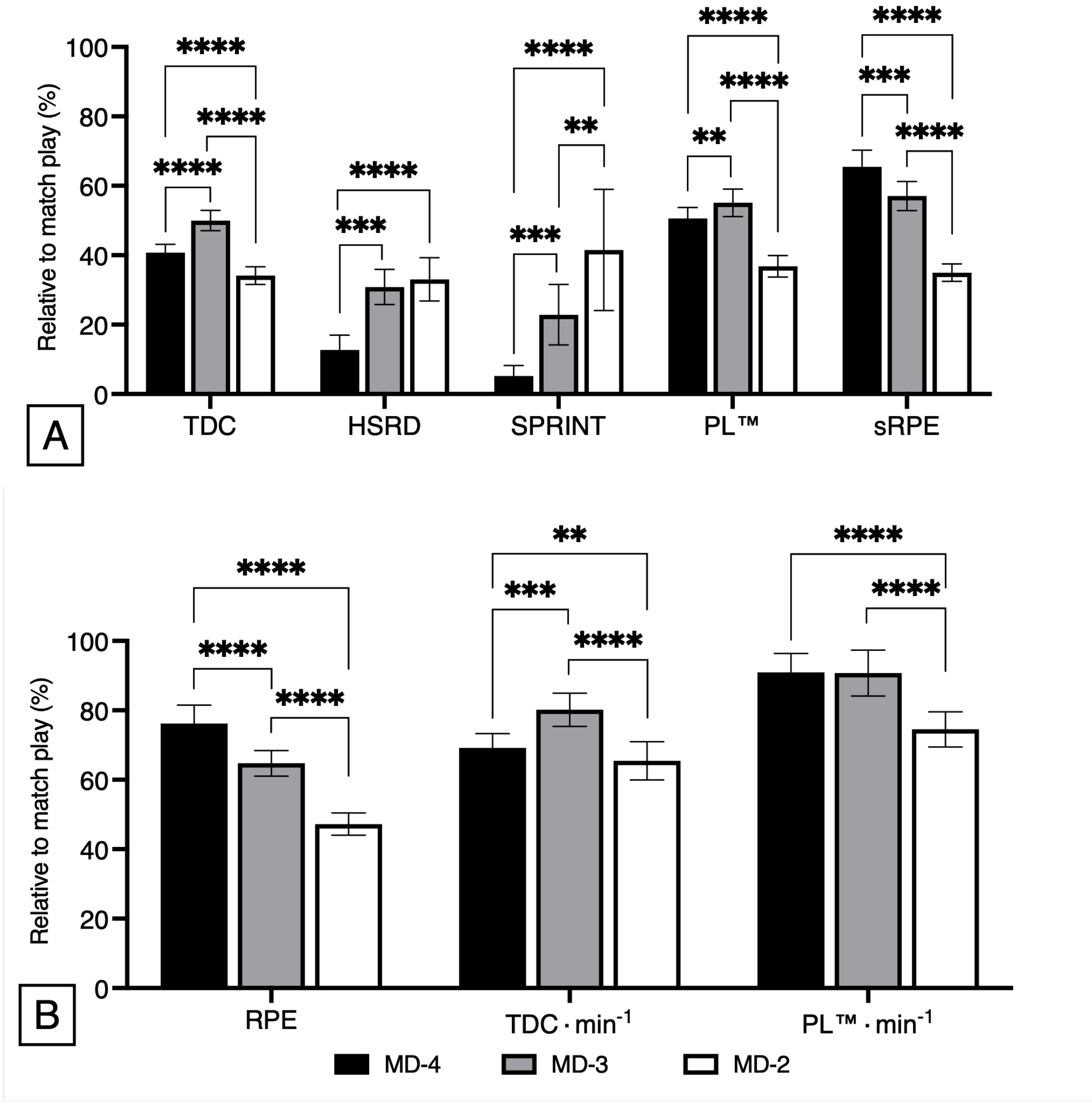

Figure 4.1: *In-week differences in A) training load variables relative to match play demands, and B) Training intensity variables relative to match play demands. Data are presented as mean ± SD. Effect size (ES) between different training sessions is indicated by the stated symbols and are marked with lines between the respective training sessions. Only ES with a substantial likelihood of difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: MD-4 = Match day-4, MD-3 = Match day-3, MD-2 = Match day-2, TDC = total distance covered, HSRD = High-speed running distance, Sprint = sprint distance, PL™ = PlayerLoad™, sRPE = session rating of perceived exertion, RPE = rating of perceived exertion, min = minute.*

Full team I-TL – E-TL relationship differences and statistical inferences within microcycles are shown in table 4.5 and 4.6. When combining training sessions within microcycles, the mean RPE-dependent I-TL – E-TL values were 906.5 ± 173.5 AU for TDC/RPE and 96.9 ± 12.6 AU for PL™/RPE. Both variables share the same pattern, with MD eliciting the greatest values, followed by MD-3, then MD-2, while MD-4 showed the lowest values. When comparing the training sessions which stimulated the greatest and lowest values, MD-3 elicited a 47.3 ± 9.5% greater TDC/RPE value and a 30.2 ± 8.6% greater PL™/RPE value than MD-4 (table 4.5).

Table 4.5: *RPE-dependent I-TL – E-TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC/RPE (AU)					
MD	1264.8 ± 75.9	vs MD-2	2.8	100/0/0	most likely
		vs MD-3	2.4	100/0/0	most likely
		vs MD-4	6.1	100/0/0	most likely
MD-2	966.2 ± 114.5				
		vs MD-3	0.7	0/5/95	very likely
		vs MD-4	2.3	100/0/0	most likely
MD-3	1042.2 ± 92.4				
		vs MD-4	3.3	100/0/0	most likely
MD-4	711.1 ± 87.5				
PL™/RPE (AU)					
MD	119.1 ± 11.0	vs MD-2	1.5	99/1/0	very likely
		vs MD-3	0.9	97/3/0	very likely
		vs MD-4	2.9	100/0/0	most likely
MD-2	99.6 ± 12.2				
		vs MD-3	0.6	0/5/95	very likely
		vs MD-4	1.3	99/1/0	very likely
MD-3	107.8 ± 12.5				
		vs MD-4	1.9	100/0/0	very likely
MD-4	83.2 ± 11.6				

The mean values for the sRPE dependent I-TL – E-TL variables when combining all training sessions within microcycles were 12.14 ± 2.68 AU for TDC/sRPE and 1.30 ± 0.21 AU for PL™/sRPE. For TDC/sRPE, MD-2 and MD elicits the greatest values with unclear differences between them, followed by MD-3, while MD-4 elicits the lowest values. In regard to PL™/sRPE, MD-2 elicits the greatest values, followed by MD, then MD-3, while MD-4 elicits the lowest values. When comparing the training sessions which produced the greatest and lowest values, MD-2 elicited a 57.9 ± 16.0% greater TDC/sRPE value and a 39.3 ± 13.6% greater PL™/sRPE value than MD-4 (table 4.6).

Table 4.6: *sRPE-dependent I-TL – E-TL variables as raw data and comparisons between days within microcycles. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC/sRPE (AU)					
MD	14.51 ± 0.98	vs MD-2	0.2	21/34/45	unclear
		vs MD-3	1.9	99/1/0	very likely
		vs MD-4	4.4	100/0/0	most likely
MD-2	14.74 ± 1.78				
		vs MD-3	1.5	99/0/0	very likely
		vs MD-4	3.2	100/0/0	most likely
MD-3	12.28 ± 1.12				
		vs MD-4	2.3	100/0/0	most likely
MD-4	9.39 ± 1.14				
PL™/sRPE (AU)					
MD	1.37 ± 0.11	vs MD-2	0.9	3/7/90	likely
		vs MD-3	2.2	100/0/0	most likely
		vs MD-4	1.9	99/0/0	very likely
MD-2	1.52 ± 0.19				
		vs MD-3	1.3	99/1/0	very likely
		vs MD-4	2.2	100/0/0	most likely
MD-3	1.27 ± 0.15				
		vs MD-4	0.9	99/1/0	very likely
MD-4	1.10 ± 0.15				

I-TL – E-TL variables and statistical inferences relative to match play demands is shown in figure 4.2. MD-2 elicited relatively the greatest values for sRPE-dependent I-TL – E-TL ratios and are the only variables that is greater than match play demands. MD-3 relatively elicits the greatest values for the RPE-dependent I-TL – E-TL variables within microcycles. MD-4 elicits the lowest values for all I-TL – E-TL variables.

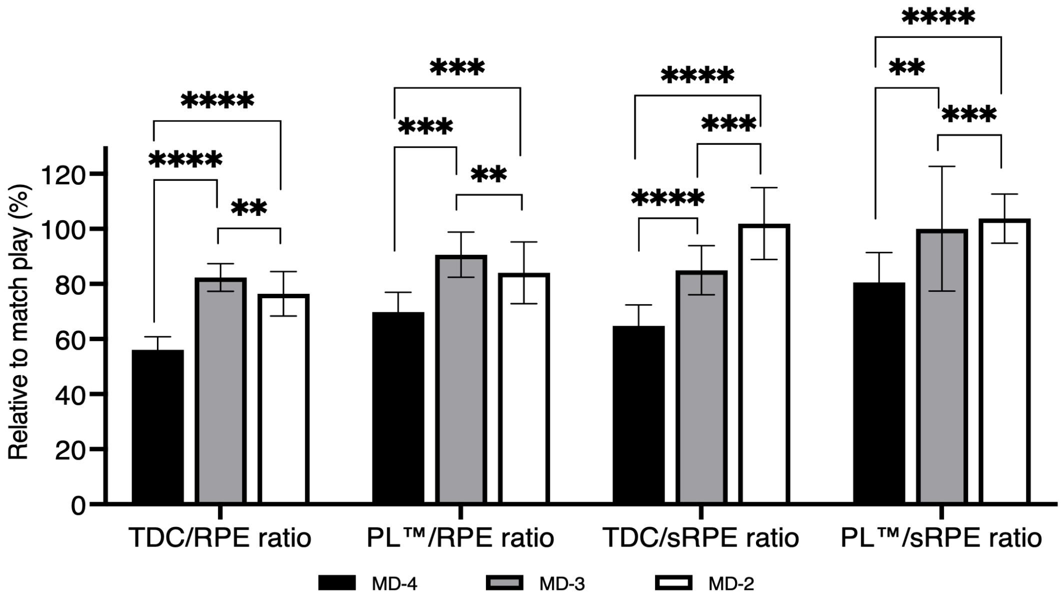

Figure 4.2: *In-week differences in the internal-external training load relationship relative to match play. Data are presented as mean ± SD. Effect size (ES) between different training sessions is indicated by the stated symbols and are marked with lines between the respective training sessions. Only ES with a substantial likelihood of difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: MD = Match day, MD-2 = Match day-2, MD-3 = Match day-3, MD-4 = Match day-4, TDC = Total distance covered, RPE = Rating of perceived exertion, PL™ = PlayerLoad™, sRPE = session rating of perceived exertion.*

4.1.2 Between position differences in TL within microcycles

For positional differences within microcycles, differences were only observed on MD, with MF likely eliciting greater values in regard to TDC·min^{-1} on MD (ES = 0.9 – 91/6/3) and in regard to PL™·min^{-1} on the same day (ES = 0.9 – 92/5/3). Taking all the other E-TL variables in consideration, small ESs and unclear differences were observed on all days within microcycles. The raw data as well as statistical inferences are presented in table Appendix 1 in the appendix. In regard to the positional differences in I-TL variables, as well in the I-TL – E-TL variables, unclear differences were found between DF and MF. Despite minor differences when looking at the raw, absolute data for all variables, all statistical tests presented large ESs with unclear inferences between them. This may potentially be a bias due to an uneven number of subjects in these variables (DF = 4, MF = 3). However, if interested in positional demands and comparisons between positions, raw data is presented in “table appendix 1” and “table appendix 2” in appendix.

4.2 Differences in training load in different mesocycles throughout the competition phase

4.2.1 Full-team differences throughout the competition phase

Full-team differences and statistical inferences for the E-TL and I-TL variables throughout the competition phase are shown in table 4.7 – 4.10. In regard to the distance-derived variables throughout the competition phase the mean TDC was 4379 ± 133 m. Meso 5 produced the greatest TDC value, with small differences to meso 3 and meso 6 and moderate differences to meso 4. Further differences observed were unclear. In regard to TDC·min^{-1} the mean intensity throughout the competition phase was 77.6 ± 11.0 m. Meso 5 elicited the greatest TDC·min^{-1} and meso 3 stimulated the lowest, and meso 4 and 6 produced possible small differences between them (table 4.7).

Table 4.7: *Distance derived TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC (m)					
Meso 3	4347 ± 262	vs Meso 4	0.2	48/37/15	unclear
		vs Meso 5	0.5	78/17/5	likely
		vs Meso 6	0.1	38/36/26	unclear
Meso 4	4277 ± 418				
		vs Meso 5	0.6	1/9/90	likely
		vs Meso 6	0.1	12/56/32	unclear
Meso 5	4574 ± 515				
		vs Meso 6	0.5	83/16/2	likely
Meso 6	4319 ± 466				
TDC·min^{-1} (m)					
Meso 3	61.5 ± 5.4	vs Meso 4	2.7	100/0/0	Most likely
		vs Meso 5	3.3	100/0/0	Most likely
		vs Meso 6	3.0	100/0/0	Most likely
Meso 4	80.5 ± 7.2				
		vs Meso 5	0.7	0/5/95	very likely
		vs Meso 6	0.3	1/35/64	possibly
Meso 5	86.0 ± 7.8				
		vs Meso 6	0.4	88/12/0	likely
Meso 6	82.6 ± 7.4				

In regard to the speed-derived variables throughout the competition phase the mean HSRD was 170.3 ± 20.3 m. Meso 6 elicited the lowest HSRD values and were different from all mesocycles. Furthermore, unclear differences were observed between the other mesocycles, other than a possible small difference between meso 4 and 6. In regard to SPRINT, the mean was 36.7 ± 8.5 m throughout the competition phase. Meso 6 produced the lowest SPRINT values, differencing from all other mesocycles. Furthermore, a possible difference between meso 3 and 4 was observed. Further differences were unclear (table 4.8).

Table 4.8: *Speed-derived TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
HSRD (m)					
Meso 3	179.2 ± 53.4	vs Meso 4	0.2	47/43/10	unclear
		vs Meso 5	0.2	15/40/44	unclear
		vs Meso 6	0.5	78/17/5	likely
Meso 4	168.8 ± 52.1				
		vs Meso 5	0.3	2/31/67	possibly
		vs Meso 6	0.4	77/22/1	likely
Meso 5	190.4 ± 79.8				
		vs Meso 6	0.6	98/2/0	very likely
Meso 6	143.0 ± 72.9				
SPRINT (m)					
Meso 3	44.00 ± 15.72	vs Meso 4	0.4	73/22/5	possibly
		vs Meso 5	0.1	40/35/25	unclear
		vs Meso 6	0.8	86/9/3	likely
Meso 4	36.57 ± 17.50				
		vs Meso 5	0.2	6/41/54	unclear
		vs Meso 6	0.5	83/15/2	likely
Meso 5	41.93 ± 25.82				
		vs Meso 6	0.6	97/3/0	very likely
Meso 6	25.05 ± 24.60				

For the accelerometer derived variables, the mean PL™ throughout the competition phase was 467.6 ± 12.9 AU. Small and moderate differences were observed between meso 3 and meso 4 and meso 3 and meso 6, respectively, with meso 3 eliciting the greatest PL ™. Furthermore, possible small differences between meso 4 and meso 5, as well as between meso 5 and meso 6, were observed as well. Further differences were unclear. For PL™·min^{-1} the mean intensity throughout the competition phase was 8.64 ± 0.38 AU. Meso 3 elicited the lowest intensity, possibly followed by meso 6, while meso 4 and meso 5 eliciting the greatest intensity with unclear differences between them (table 4.9).

Table 4.9: *Accelerometer-derived TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
PL™ (AU)					
Meso 3	481.5 ± 21.7	vs Meso 4	0.5	79/18/3	likely
		vs Meso 5	0.1	41/43/16	unclear
		vs Meso 6	0.6	88/11/2	likely
Meso 4	460.4 ± 53.7				
		vs Meso 5	0.2	3/42/56	possibly
		vs Meso 6	0.1	34/60/6	unclear
Meso 5	475.0 ± 62.7				
		vs Meso 6	0.3	72/26/2	possibly
Meso 6	453.4 ± 53.0				
PL™·min^{-1} (AU)					
Meso 3	8.10 ± 0.60	vs Meso 4	1.0	98/2/0	Very likely
		vs Meso 5	0.9	98/2/0	very likely
		vs Meso 6	0.7	94/6/1	likely
Meso 4	8.93 ± 0.92				
		vs Meso 5	0.0	22/63/15	unclear
		vs Meso 6	0.3	68/31/1	possibly
Meso 5	8.90 ± 0.96				
		vs Meso 6	0.3	64/36/1	possibly
Meso 6	8.64 ± 0.84				

In regard to the internal-derived TL variables, the mean RPE throughout the competition phase was 5.32 ± 0.30 AU. Meso 4 and meso 6 elicited the greatest intensity with unclear differences between them, then followed by meso 3 and meso 5, with unclear differences between them. For the sRPE load throughout the competition phase, the mean was 423.12 ± 21.19 AU. Meso 3 and Meso 4 (unclear difference between them) provoked the greatest sRPE load with likely moderate differences to meso 5, which caused the lowest. Furthermore, unclear differences were observed between meso 4 and the other mesocycles (table 4.10).

Table 4.10: *Internal-derived TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
RPE (AU)					
Meso 3	5.10 ± 0.59	vs Meso 4	0.6	87/11/2	likely
		vs Meso 5	0.1	41/32/27	unclear
		vs Meso 6	0.9	3/7/89	likely
Meso 4	5.47 ± 0.43				
		vs Meso 5	0.7	88/10/2	likely
		vs Meso 6	0.4	12/23/66	unclear
Meso 5	5.04 ± 0.65				
		vs Meso 6	1.0	1/3/96	very likely
Meso 6	5.67 ± 0.50				
sRPE (AU)					
Meso 3	439.2 ± 52.6	vs Meso 4	0.4	71/22/7	unclear
		vs Meso 5	0.7	86/10/4	likely
		vs Meso 6	0.0	36/30/34	unclear
Meso 4	420.4 ± 25.0				
		vs Meso 5	0.5	76/17/7	unclear
		vs Meso 6	0.5	11/19/71	unclear
Meso 5	394.2 ± 57.4				
		vs Meso 6	0.8	92/7/2	likely
Meso 6	438.7 ± 40.8				

Full-team differences relative to match play demands throughout the competition phase is shown in figure 4.3. For speed-derived TL variables, meso 6 relatively elicited the lowest values for both HSRD and SPRINT, with no further differences between the other mesocycles. For TDC·min^{-1} meso 5 relatively caused the greatest intensity, with differences between the other mesocycles, and meso 3 relatively provoked the lowest values throughout the competition phase. Furthermore, TDC·min^{-1} had differences between all mesocycles except between meso 4 and meso 6. For PL™·min^{-1}, differences were solely observed between meso 3 and the rest of the mesocycles. In regard to the internal derived TL variables, differences in sRPE were observed between meso 5 and meso 3, and meso 5 and meso 6. In regard to RPE, differences were observed throughout the competition phase except for between meso 3 and 5 and between meso 4 and meso 6 (figure 4.3).

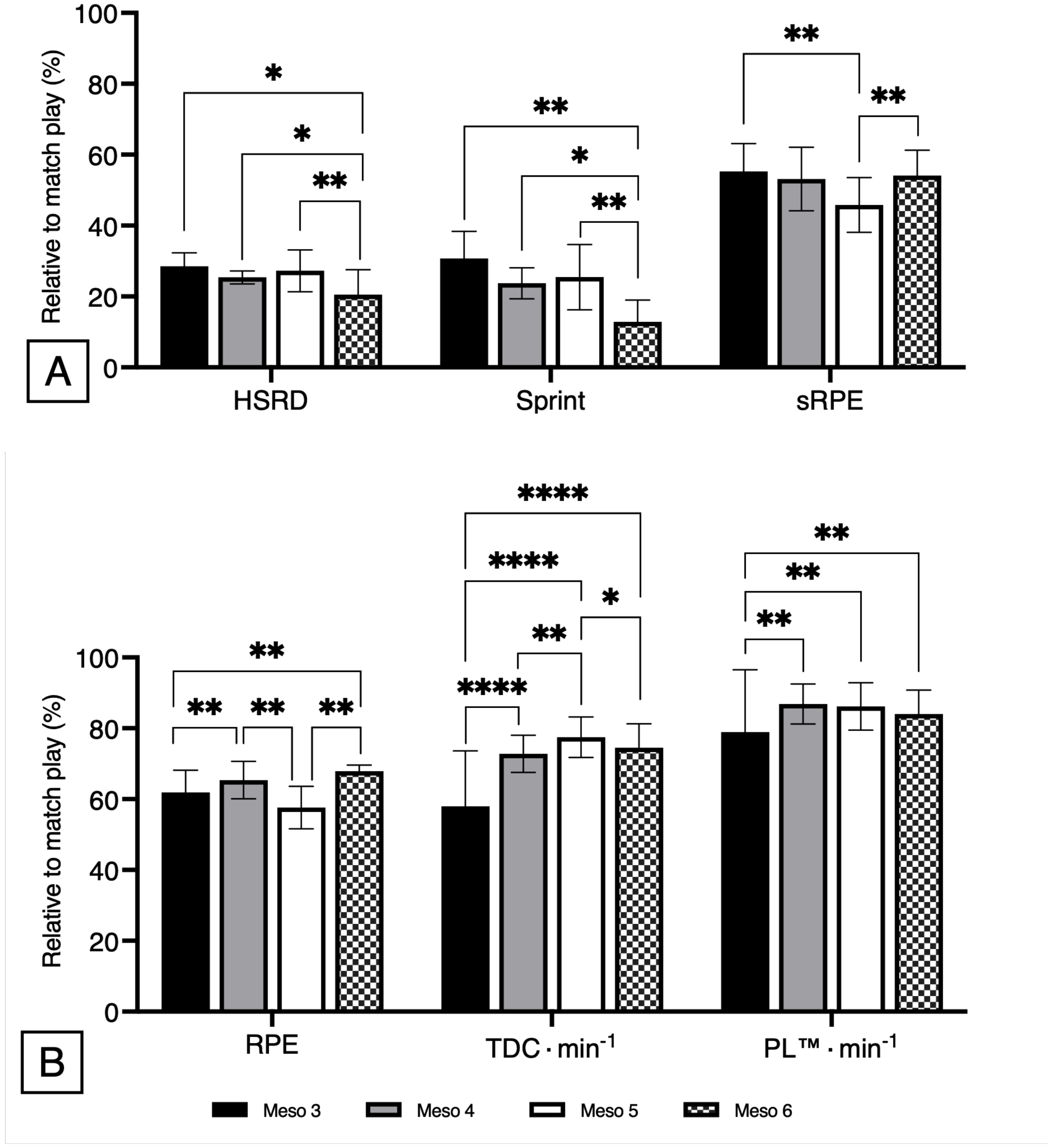

Figure 4.3: *Full team differences in A) training load variables and B) training intensity variables relative to match play demands throughout the competition phase divided into 4 mesocycles. Data are presented as mean percentage of match play ± SD. Effect size (ES) between different mesocycles is indicated by the stated symbols and are marked with lines between the respective mesocycles. Only ES with a substantial likelihood of difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: TL = training load. Meso = mesocycle. TDC = total distance covered. Min = minute. HSRD = high-speed running distance. Sprint = sprint distance. PL™ =PlayerLoad™. RPE = rating of perceived exertion. sRPE = session rating of perceived exertion.*

Mean and individual data for TDC and PL ™ throughout the competition phase is shown in figure 4.4. In regard to TDC, meso 5 elicited the greatest TDC, with alteration between the other mesocycles. Differences between the other mesocycles were not observed. For PL ™, relative differences were observed between meso 3 and meso 4 as well as between meso 3 and meso 6. Further differences between mesocycles were not observed.

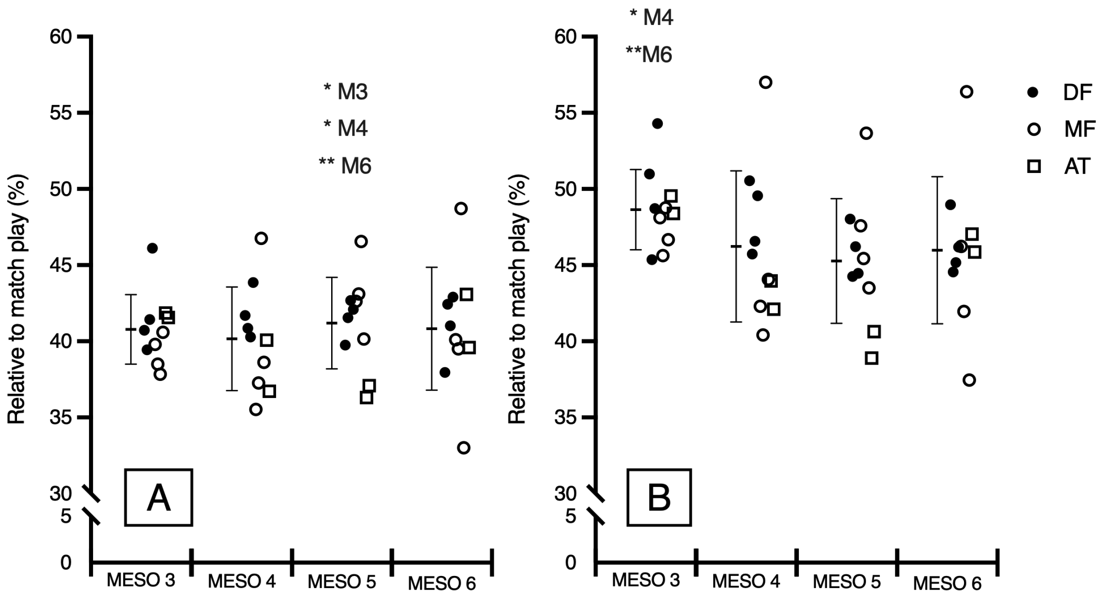

*Figure 4.4: Full team mean ± SD and individual data for all playing positions in all mesocycles, relative to match play load, are shown for TDC (A) and PL ™ (B). Effect size (ES) between different mesocycles is indicated by the stated symbols and are marked with mesocycle number. Only ES with a substantial likelihood of difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: Meso and M (3, 4, 5, 6) = mesocycle, DF = defenders. MF = midfielders. AT = attackers.*

4.2.2 Positional differences throughout the competition phase

For positional differences throughout the competition phase, TL differences were only observed in Meso 5 on distance-derived TL variables and accelerometer-derived TL variables. In meso 5, MF likely caused a greater TDC with a moderate ES (0.6 – 89/9/2) and likely produced a greater TDC·min^{-1} with a moderate ES (0.8 – 91/6/3) than DF. Additionally, in the same Meso, MF likely stimulated a greater PL™ with a moderate ES (0.6 – 87/11/2) and likely stimulated a greater PL™·min^{-1} with a moderate ES (0.8 – 90/8/3) than DF. Further differences were unclear in all other variables throughout the competition phase and will therefore not be presented in the thesis. However, if interested, the raw data is presented in the appendix in "table appendix 3".

4.3 Differences in the relationship between external and internal training load variables throughout the competition phase

4.3.1 Full-team differences in the I-TL – E-TL relationship throughout the competition phase

Full team differences and statistical inferences in the I-TL – E-TL relationship throughout the competition phase are shown in table 4.11 and 4.12. For the RPE-dependent variables, the mean TDC/RPE values throughout the competition phase was 894.6 ± 82.4 AU. Meso 6 elicited the lowest values with differences between all the other mesocycles. Furthermore, differences were observed between meso 4 and meso 5. For PL™/RPE, the mean values throughout the competition phase was 95.9 ± 9.2 AU. This variable shares the same pattern as TDC/RPE (table 4.11).

Table 4.11: *RPE-dependent I-TL – E-TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC/RPE (AU)					
Meso 3	926.6 ± 124.4	vs Meso 4	0.6	76/15/8	unclear
		vs Meso 5	0.3	17/24/59	unclear
		vs Meso 6	0.9	86/9/5	likely
Meso 4	856.5 ± 87.2				
		vs Meso 5	0.7	1/7/93	likely
		vs Meso 6	0.5	78/19/3	likely
Meso 5	992.6 ± 228.1				
		vs Meso 6	0.9	98/2/0	very likely
Meso 6	803.6 ± 123.8				
PL™/RPE (AU)					
Meso 3	102.5 ± 16.0	vs Meso 4	0.7	81/13/6	unclear
		vs Meso 5	0.1	29/31/40	unclear
		vs Meso 6	1.1	93/5/2	likely
Meso 4	92.4 ± 11.6				
		vs Meso 5	0.5	1/13/86	likely
		vs Meso 6	0.6	91/8/1	likely
Meso 5	104.3 ± 27.2				
		vs Meso 6	0.8	97/3/0	very likely
Meso 6	84.5 ± 13.5				

In regard to the sRPE dependent I-TL – E-TL variables throughout the competition phase, the mean TDC/sRPE value was 12.01 ± 1.08 AU. Differences were only observed between meso 4 and meso 5 and between meso 5 and meso 6. For the PL™/sRPE variable, the mean value throughout the competition phase was 1.29 ± 0.12 AU. Differences were only observed between meso 3 and meso 6, between meso 4 and meso 5 and lastly between meso 5 and meso 6 (table 4.12).

Table 4.12: *sRPE-dependent I-TL – E-TL variables as raw data and comparisons between mesocycles throughout the competition phase. %likelihood being higher/trivial/lower.*

			Magnitude of differences		
	Mean ± SD		Effect size	%likelihood	Rating
TDC/sRPE (AU)					
Meso 3	12.13 ± 1.94	vs Meso 4	0.4	67/21/12	unclear
		vs Meso 5	0.5	12/19/69	unclear
		vs Meso 6	0.5	71/17/12	unclear
Meso 4	11.38 ± 1.26				
		vs Meso 5	0.8	96/4/0	very likely
		vs Meso 6	0.2	49/42/10	unclear
Meso 5	13.48 ± 3.05				
		vs Meso 6	0.9	98/2/0	very likely
Meso 6	11.04 ± 1.83				
PL™/sRPE (AU)					
Meso 3	1.37 ± 0.22	vs Meso 4	0.7	81/13/6	unclear
		vs Meso 5	0.1	25/30/45	unclear
		vs Meso 6	0.9	88/8/4	likely
Meso 4	1.23 ± 0.16				
		vs Meso 5	0.6	1/8/91	likely
		vs Meso 6	0.3	72/26/2	possibly
Meso 5	1.41 ± 0.36				
		vs Meso 6	0.8	97/3/0	very likely
Meso 6	1.16 ± 0.20				

Full team differences and statistical inference relative to match play in the I-TL – E-TL relationship is shown in figure 4.5. TDC/RPE min relatively ranges between 62.8 ± 9.6% to 76.8 ± 7.1% of match play demands throughout the competition phase, where meso 6 showed the lowest values. In regard to PL™/RPE, variables relatively ranged from 70.3 ± 8.5% to 85.8 ± 3.1% of match play demands, whereas meso 6 showed the lowest value. When analyzing TDC/sRPE, the variable ranged from 74.7 ± 3.4% to 91.7 ± 8.9% of match play demands throughout the competition phase, and differences were found between meso 5 and meso 6, and between meso 5 and meso 4. For the PL™/sRPE variable, a range of 77.3 ± 9.3% to 101.4 ± 8.2% of match play was observed. Moreover, both meso 3 and meso 5 relatively exceeds match play demands.

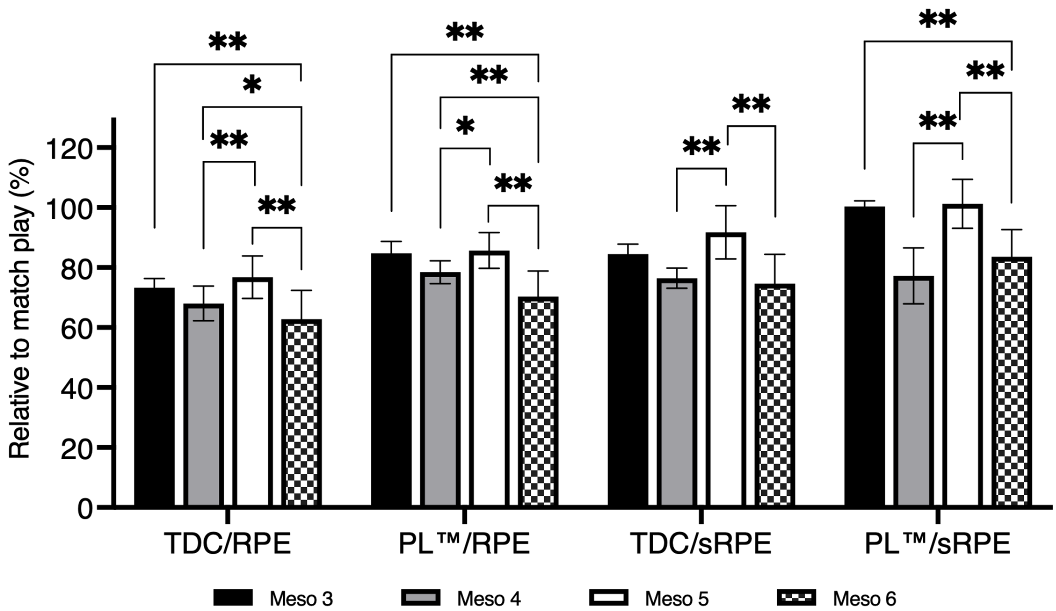

Figure 4.5: *Full team differences in the relationship between internal and external training load variables relative to match play demands throughout the competition phase, divided into 4 mesocycles. Data are presented as the mean percentage of match play ± SD. Effect size (ES) between different mesocycles is indicated by the stated symbols and are marked with lines between the respective mesocycles. Only ES with a substantial likelihood of difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: Meso = mesocycle, TDC = total distance covered. RPE = rating of perceived exertion. PL™ = PlayerLoad™. sRPE = session rating of perceived exertion.*

4.3.2 Positional differences in the I-TL – E-TL relationship throughout the competition phase

For positional differences in the I-TL – E-TL relationship throughout the competition phase, unclear differences were found between positions in all variables in all mesocycles. All ESs ranged between 0.3 – 1.1 (small to moderate differences) with a %likelihood indicating that DF elicited the greatest values. However, when looking at the raw data without statistical inferences, differences seems to be minor, and the results may be biased due to the uneven number of subjects (DF; 4, MF; 3). If interested, the results from these variables are not presented in the thesis but is listed in the appendix as raw data for all positions on all mesocycles in "table appendix 4".

5. Discussion

The aim of this thesis was to investigate 1) potential differences in measured TL and intensity within microcycles, 2) potential differences in measured TL and intensity in different mesocycles throughout the competition phase, and 3) potential differences in the relationship between the player's E-TL and I-TL throughout the competition phase. Potential differences were examined with the use of tracking devices (GPS and triaxial accelerometer) and self-reported I-TL. Briefly, results from this thesis indicate that TL throughout the competition phase is variated, depending on which variables examined. Moreover, there were shown differences between training days within microcycles, suggesting a tapering strategy preceding match play to increase competitive readiness and performance.

5.1 Differences in TL within microcycles

The main findings within microcycles were that MD produced the greatest load compared to training sessions, and differences between all training sessions for all variables, except for HSRD between MD-3 and MD-2, and for PL™·min^{-1} which only showed differences between MD-2 and the remaining training sessions. Furthermore, results indicate a tapering strategy preceding match play for all variables except for HSRD and SPRINT, which had increased values prior to match play observed.

MD provoked the greatest load within microcycles. This is consistent with previous research (chapter 2.5.2). Although some studies (Abbott et al., 2017; Gabbett, 2016) have suggested that TL variables should exceed match demands, Baptista et al. (2019) propose that simply reproducing match demands in training sessions would be impractical due to high match load demands and the associated injury risk. Contrary to several studies, Abbott et al. (2017) reported that training games from 4v4 up to 10v10 players produce a greater mean TDC·min^{-1} compared to match play, and is likely due to methodological differences; whereas most studies have reported the mean values throughout each training session, Abbott et al. (2017) reported values solely derived from the training game within each training session. Thus, possibilities exist that studies (including this thesis) report underestimated values of intensity within microcycles, as different contexts within a training session are performed with different intensities. However, suggestions from Batista et al. (2019) is still relevant, as high intensities over a sufficient time period (i.e. the whole training session) could potentially increase the risk of injury and recovery time (Soligard et al., 2016).

5.1.1 Differences in GPS derived TL variables

In regard to TDC and TDC·min^{-1}, MD-3 produced the overall greatest values compared to MD-4 and MD-2 (Table 4.1). The findings are contrary to Malone et al. (2015) that observed no differences within microcycles with the exception of MD-1, that produced the least TDC. However, observed differences in TL occurred, and other research has suggested that TL must be varied to ensure optimal training adaptions and reduce the accumulation of fatigue (Brink et al., 2014). Moreover, the decrease in both TL and intensity on MD-2 is in line with several other studies, suggesting a tapering strategy to unload players preceding match play (Akenhead et al., 2016; Anderson et al., 2016; Martín-García et al., 2018; Oliveira et al., 2019; Owen et al., 2017).

The absolute mean TDC within a week (4438 m and 79.2 m·min^{-1}) is unique compared to previous research, emphasizing the differences between coaching strategies in different clubs. However, the values still falls within the boundaries of values previously observed, ranging from 3772 m (Gaudino et al., 2013) to 6871 m (Owen et al., 2017). These values can be used as reference values for players on elite level that can be considered when planning training sessions (Malone et al., 2015). Moreover, Stevens et al. (2017) suggested the expression of TL in relation to match load to be valuable in terms of training prescription as well as an applicable tool for communication between practitioners, coaches and players. The mean relative values observed in this thesis ranged from 34-50% for TDC and 65.5-80.2% for TDC·min^{-1} (figure 4.1). To the authors extent of knowledge, this is the first thesis to provide relative values for TDC·min^{-1} within microcycles, showing a periodization strategy in which intensity is decreased preceding match play along with the gross TL. Despite differences in absolute values, the periodization strategy for both TDC and TDC·min^{-1} is similar to what is reported by Anderson et al. (2016), with the greatest value produced by MD-3, followed by MD-4, then MD-2. Moreover, TDC values are within the range of what has previously been observed in Norwegian premier league footballers (31-61%; Baptista et al., 2019). However, the TDC values from this study are lower compared to the greatest relative load reported by Martín-García et al. (2018), as well as the reported range of 35-67% on Dutch football players (Stevens et al., 2017).

Additionally, the result lies in the bottom tier of previously reported values (both relative and absolute) along with the fact that this thesis excluded MD-1. When considering that previous reports have found the least TL generated on this day, these results should be generalized with caution.

Interestingly, findings regarding periodization on HSRD and SPRINT are contrary to previous research (table 4.2). An increase in high intensity running distance is associated with an increased injury predisposition due to the effects of accumulative fatigue (Owen et al., 2017). Furthermore, previous research has reported a greater TL produced on training sessions early to middle stages of a planned microcycle, with the aim to induce a stimulus on days where the carryover of fatigue is minimal. In addition, it may have a enhancing effect on the physical development of players (Martín-García et al., 2018; Owen et al., 2017). Despite differences in the periodization, the mean HSRD value observed in the thesis falls within the boundaries (99.5-203 m) of previously reported values (Akenhead et al., 2016; Gaudino et al., 2013; Malone et al., 2015; Stevens et al., 2017), and the range of 13 – 33% of match play is similar to values reported by (Stevens et al., 2017). Furthermore, the mean absolute SPRINT value is greater than formerly observed values (19-22 m), but when expressed as relative to match play (figure 4.1A), the range of 5-42% of match play is similar to reports regarding the greatest relative SPRINT within microcycles (Akenhead et al., 2016; Gaudino et al., 2013; Martín-García et al., 2018). Moreover, when summarizing all relative and absolute values within microcycles, HSRD (76%, 525.2 m) and SPRINT (69%, 113.7 m) is greater than previously observed in Norwegian elite football (Baptista et al., 2019). Thus, findings from this study suggests a difference in coaching strategies. However, due to methodological differences, particularly in regard to different speed thresholds for each speed variable, interpretation must be done with caution.

Martín-García et al. (2018) reported a contextualized training program, showing the use of SSG and the focus on strength and power capabilities on MD-4. Interestingly, despite the use of SSGs, results regarding other TL variables are contrary to those observed in this thesis, as MD-4 produced the greatest values for sprint and high-speed running distance (45% and 37% of match load, respectively). Based on previous findings regarding SSG, this is contrary to the literature, as SSG with a small pitch area is associated to induce greater values on other TL variables (insert). It can therefore be questioned whether other activities in the training session caused the reported values for high-speed running and sprint.

The increased values in HSRD and SPRINT preceding match play can have possible consequences regarding recovery, as bouts of maximal effort are association an energy turnover mainly derived from anaerobic processes along with a great contribution of fast twitch muscle fibers (McArdle, Katch, & Katch, 2007; Spencer, Bishop, Dawson, & Goodman, 2005). The induced fatigue is associated with a lower pH value due to accumulation of inorganic phosphate and a greater H^+ concentration, as well as rupture in muscle fibers (McArdle et al., 2007). However, a decrease in all other TL variables on the training session (MD-2, table 4.1 – 4.6 and figure 4.1) were observed, which may be a strategy implemented to "compensate" for the greater speed distances and the associated accumulated fatigue. More research is needed to investigate the biological responses and their association with increased speed distances despite lower values in other TL values.

5.1.2 Differences in accelerometer derived TL variables

For PL™, results derived from this thesis shows for that MD-3 provoked the greatest value, followed by MD-4, then MD-2 (table 4.3, figure 4.1A). To the researchers knowledge, only one research paper has examined the variation in PL™ within microcycles, expressed as days in proximity to match play (Akenhead et al., 2016). Similar results were observed, with the second training session within the microcycle eliciting the greatest value, followed by a decrease preceding match play. However, the weekly mean value (523 AU) observed by Akenhead et al. (2016) is greater compared to the observed value in this thesis, which is likely due to the overall greater TLs provoked throughout the microcycle. Also, it emphasizes the individual aspect of coaching strategies. Moreover, the summarized PL™ within microcycles is 288 AU greater than values observed in elite adolescent rugby players (Phibbs et al., 2017). This may be due to the decreased TDC accumulated within microcycles, which has been previously reported to have a strong to nearly perfect relationship between them (Gallo et al., 2015; Polglaze et al., 2015).

Interestingly, despite a lower TL in several variables, including PL™, on MD-4 compared to MD-3, similar intensities in regard to PL™·min^{-1} were observed (table 4.3, figure 4.1B). Given the fact that similar intensities were produced, the greater PL™ observed on MD-3 is probably caused by a longer training duration. Furthermore, Dalen et al. (2019) suggests PL™ and PL™·min^{-1} declines with larger pitch size, which is similar to results found on MD-2, which had large-sided games as training context. Moreover, although a reduction in TL and a lower intensity in terms of TDC and TDC·min^{-1} was observed on MD-4, the equality in PL™·min^{-1} could possibly be caused by movements not examined in this thesis. Indeed, Baptista et al. (2019) and Stevens et al. (2017) observed a greater contribution of accelerations and decelerations during SSGs, which also happened to be the context in MD-4 in this thesis. Moreover, the findings of PL™ elicited during training sessions to be 2 to 4 times greater than match load, and simultaneously exceeding match loads for accelerations and decelerations, suggests an overuse of SSG in Portuguese football (Clemente et al., 2019). In addition, increased force in heel-strike during high intensity running has been reported to affect the vertical component of the calculation of PL™ (Malone et al., 2017), which is likely why Beenham et al. (2017) observed a greater PL·min^{-1} with increased high intensity running distances.

5.1.3 Differences in internal derived TL variables

In terms of quantification on I-TL, the use of RPE and sRPE has been regarded as the single best indicator of the degree of internal physical strain (Juhari et al., 2018), and has been greatly applied in football and other intermittent team sports to quantify I-TL (chapter 2.3.1 and 2.3.4). The results indicate a near perfect linear tapering strategy preceding match play, with MD-4 provoked the greatest load (sRPE) and the greatest intensity (RPE), followed by MD-3, then MD-2 in terms of both absolute and relative values (table 4.4, figure 4.1). Albeit differences in tapering strategies within studies, a decrease preceding match play is in line with previous research (chapter 2.5.2). The average sRPE value observed within microcycles is greater compared to the 272 AU reported by Malone et al. (2015). Moreover, Owen et al. (2017) reported a mean weekly sRPE value of 453 AU which is similar to values observed in this thesis. However, both aforementioned studies covered greater TDC compared to this thesis and were collected on two different teams competing in the same league, which may predicate physical demands in elite English football. Furthermore, comparisons between groups of subjects should be done with caution, as a high intra variability in the internal response to the same E-TL may be present (Schwellnus et al., 2016). Moreover, Owen et al. (2017)

reported a lower sRPE on MD-2 versus MD-4 despite a greater TDC·min^{-1}, suggesting it to be a result of the coaching aiming to reduce the effects of accumulative fatigue based on the previous days intensity. This was not observed in this thesis as MD-2 showed the lowest value for both RPE, sRPE and TDC·min^{-1}. However, the suggestion made may still be highly relevant.

The fact that the only variables that elicited the greatest values exclusively on MD-4 were sRPE and RPE indicate a training session in which variables not included in the thesis had the greatest contribution to the associated I-TL. When contextualizing the training content, MD-4 consisted of SSGs, and previous research has observed an increase in intensity measures when absolute playing areas is limited (Abbott et al., 2017; Dalen et al., 2019). Moreover, SSG has been related to a format in which effectively induces football specific movement patterns under fatigue, such as accelerations, decelerations and change of directions (Baptista et al., 2019; Hill-Haas et al., 2011; Stevens et al., 2017). Furthermore, RPE intensities induced on MD-4 may have contributions from tasks that are not included in the thesis, such as jumping, tackling, grappling, and it is likely that the frequency of these tasks increase with a reduction in players on the pitch along with a smaller pitch area (Hill-Haas et al., 2011). Moreover, a frequency boost in these variables may also contribute to a higher concentration of blood lactate, which has previously been correlated with RPE (Coutts et al., 2009).

5.2 Differences in TL throughout the competition phase

The main findings in regard to differences throughout the competition phase were I) decreases in HSRD and SPRINT in the last meso, while the other mesocycles elicited similar TLs, II) a greater TDC and TDC·min^{-1} in meso 5 despite lower RPE and sRPE values compared to the other mesocycles were reported, III) meso 3 elicited the lowest intensity for TDC·min^{-1} compared to the other mesocycles although TDC produced in the corresponding mesocycle only differed to meso 5, IV) meso 3 elicited the lowest intensity for PL™·min^{-1} compared to the other mesocycles although PL™ produced in meso 3 were greater compared to meso 4 and meso 6, and V) intensity measures of TDC·min^{-1} had the most differences, with differences throughout all mesocycles except between meso 4 and meso 6.

Some previous studies have reported a highly monotonous TL throughout the competition phase. It is likely due to a superior focus on tactical and technical skills, while maintaining a base of physical conditioning, and hence suggesting that there is an evident uniformity in output across the training content to accommodate competitive seasonal match demands (Brink et al., 2014; Owen et al., 2017; Reilly, 2007). Moreover, the statement made Malone et al. (2015) regarding training programs remaining constant for elite football teams due to the need to win matches that does not allow the reaching of a specific peak for strength and conditioning is supportive to the aforementioned suggestions. Moreover, the similarity in TL throughout the competitive phase is supported further with the fact that the greater TDC reported in the first compared to the last mesocycle reported by Malone et al. (2015) was likely due to the coaches' still having some emphasis on physical conditioning. Albeit minor differences, Oliveira et al. (2019) observed tendencies of decrements throughout the season, with the mesocycles in the early stages provoking a greater TL compared to the last. Also, the 5th meso produced the lesser TL, and the differences between the aforementioned research may be caused by methodological limitations, such as including blocks in which abnormalities in their normal training routine occurred (Oliveira et al., 2019).

Although some studies regarding seasonal TL quantification in other team sports have reported contrary results, methodological differences may be the cause, such as including GWs with >1 game, and oppositely, including GWs with no games observed, which has shown to alternate TL to compensate for either more or less match load (Conte et al., 2018; Miloski et al., 2016; Paulauskas et al., 2019). However, Ritchie et al. (2016) observed a greater PL™ produced in the 3rd meso compared to the 1st and 4th, along with a greater HSRD. A possible explanation may be due to the increased heel-strike contributor to the y-axis on the calculation of PL™ (Malone et al., 2017).

Interestingly, results from this thesis show decreases in HSRD and SPRINT in meso 6 compared to the other mesocycles, and no further differences between the remaining mesocycles. Although possibly small differences between meso 4 and 5 for HSRD and between meso 3 and 4 for SPRINT, the magnitude were considered not substantial (table 4.8, figure 4.3A). The decrease is contrary to previous research regarding seasonal TL. However, suggestions from Malone et al. (2015) regarding the importance to win matches exceeding the need to reach specific physical peaks may be of importance when discussing the decrease. Link and de Lorenzo (2016) emphasized that the competitive season is somewhat dynamic. As the importance of each match is directly the same in all matches (i.e. 3 points), the need to win can become much clearer at the late stages of the season. For instance, for a team fighting for the title or to avoid relegation, every match played late in the season is commonly referred to as a "6-point game". Thus, the decrease in the respective TL variables in meso 6 may be a coaching-induced strategy to prevent accumulation of fatigue preceding "more important" matches, and therefore be in line with suggestions made by Malone et al. (2015). Moreover, Owen et al. (2017) reported influences in TLs depending on match conditions, which supports aforementioned suggestions even further. However, questions arise when considering whether the decrease in HSRD and SPRINT was beneficial or not, as no assessments were made.

Remarkably, meso 5 produced the greatest TL in regard to TDC (table 4.7, figure 4.4A) and TDC·min^{-1} (table 4.7, figure 4.3B), and simultaneously provoking the lowest sRPE and RPE value throughout the season (table 4.10, figure 4.3). Although only observed within microcycles, a similar results were reported by Owen et al. (2017), with a greater TDC·min^{-1} despite lower I-TL reported on MD-2. The authors further suggest it to be a result of the coaches aiming to reduce the effects of accumulative based on the previous days' intensity. A possible explanation may be a superior status in regard to physical conditioning on the players. However, although the prior meso elicited greater sRPE and RPE values compared to distance derived variables, generalizing the suggestion made by Owen et al. (2017) to the results from this thesis should be done with caution. Firstly, no physiological assessments were performed and thus, the potential carryover of fatigue and physiological adaptions are unknown, and secondly, Owen et al. (2017) is focusing on a day to day variation, while results from this thesis spans over weeks and months with a continuous training program. Hence, the increased distance derived values with lesser I-TL values may be due to factors not accounted for in the thesis' study design. Possibly, another study design, such as expressing the mean values from every different training session within a mesocycle, and then comparing different mesocycles throughout the competition phase, could potentially examine the differences in a more sensitive method.

The observed results for TDC·min^{-1} and PL™·min^{-1} is contrary to previous studies, showing either trivial or a higher TL in the early stages of the competition phase in football and Australian rules football (Malone et al., 2015; Oliveira et al., 2019; Ritchie et al., 2016). For the accelerometer derived values (table 4.9, figure 4.3B, Figure 4.4B), PL™ values were greater in meso 3 compared to meso 4 and meso 6, despite a reduced intensity in meso 3 and a similar intensity throughout the other mesocycles. Moreover, for the distance derived variables (table 4.7, figure 4.3B, figure 4.4A), the greatest TDC was observed in meso 5 with differences compared to the remaining mesocycles, and no further differences between the other. Similarly, the greatest TDC·min^{-1} was also observed in meso 5 with substantial differences compared to all other mesocycles, and further differences between all other mesocycles with the exception of meso 4 vs. meso 6. However, only a small ES was observed for TDC, albeit a very large ES for TDC·min^{-1} between meso 5 and 3, suggesting a probability of greater magnitude for intensity compared to TL. These findings emphasize the possibility of a longer duration of training sessions in meso 3, with accordingly similar or greater TL values, which is one of the key components in TL adjustment (Bompa & Buzzichelli, 2018; Hallén & Ronglan, 2011).

Interestingly, the low intensity reported in meso 3 occurred at a time period in which the club had assigned a new head coach, suggesting the reduced intensity was possibly caused by the adjustment to the coach’s training regime and coaching philosophy. Moreover, meso 3 occurred just prior and after the summer break. According to the observations made by Oliveira et al. (2019), Christmas break occurred in the mesocycle that elicited the lowest TL, suggesting that abnormalities appeared due to the holiday as well as a tighter match scheduling, and thus reducing TL to prevent overloading the players prior to match play. The reduction in TL when a tighter match schedule is present has also been suggested in basketball (Manzi et al., 2010). However, as GWs containing >1 game were excluded from this thesis, possible similarities in relation to other studies are limited. Moreover, as training frequency was constant with similar recovery time between all training sessions throughout the season, it is very likely that the main altered component to variate TL and intensity was the duration. This is also why the intensity measure of TDC·min^{-1} was observed to have the most variations throughout the season.

5.3 Differences in the I-TL – E-TL relationship

To the authors knowledge, this is the first study to present differences in the I-TL – E-TL relationship presented as different ratios. Thus, this thesis suggested a new, practical approach to assess the relationship between them. Moreover, the expression of the relationship as relative to match play, could possibly emphasize whether match specific internal responses were obtained during training sessions, and possibly how the relationship varied throughout the competition phase.

Present results within microcycles indicates that different training contents elicits different patterns in the relationship between I-TL and E-TL (figure 4.2, table 4.5 and 4.6). For instance, MD-4 showed the greatest values for I-TL valuables despite lower values in E-TL. Therefore, it is suggested that other mechanisms beyond this thesis' methodological approach to be the substantial descriptor to the corresponding I-TL, such as accelerations and decelerations. The training content in MD-4 was SSGs, which previous studies has reported to be the main contributor to acceleration and deceleration load (Abbott et al., 2017; Baptista et al., 2019). Furthermore, the progressive increase for sRPE dependent relationships preceding match play may be a result of the corresponding increase in pitch size. Thus, when using TDC and PL™ as a descriptor for sRPE, the values on MD-3 and MD-2 indicate a more match specific internal response to the E-TL.

Although relatively large differences between match load and elicited TL in MD-2 for all variables, the sRPE dependent ratios exceed match demands. A training content with similar movement patterns to actual locomotor characteristics in match play is therefore suggested. Wiig et al. (2019) proposed that sRPE first and foremost reflects the total work completed, which is strongly dependent on the session duration, because all work is quantified regardless of intensity. In regard to these statements, it is likely that the differences in elicited TL between MD and MD-2 are a consequence of a lower intensity, as a greater intensity with an equal duration would increase TDC and PL™. accordingly. However, due to methodological limitations regarding physiological assessments, definite statements are limited. Nonetheless, the differences in the ratios within microcycles highlight the importance of concurrent monitoring of both internal and external TL, as it can assist to achieve the desired training outcome and reduce injury risk (Soligard et al., 2016).

Differences in the I-TL – E-TL relationship throughout the competition phase indicates either a greater RPE value to the same E-TL, or oppositely, a reduced TDC and PL™ to the same self-reported RPE, in the last meso compared to all other mesocycles (table 4.11, figure 4.5). As athletes with a greater VO_2-max has been reported to rate a lower RPE value (Weaving, Marshall, Earle, Nevill, & Abt, 2014), present results could indicate a reduced physical conditioning. However, due to RPE's multifactorial and complex mediators such as experience and phycological mechanisms such as stress, factors previously discussed regarding match importance should also be considered. (Gallo et al., 2015; Link & de Lorenzo, 2016; Renfree, Martin, Micklewright, & St Clair Gibson, 2014). Nonetheless, generalizability of the results are limited due to unclear relationships between RPE and the use one E-TL as descriptor (McLaren et al., 2018).

As large relationships were reported for sRPE and the respective E-TL variables (McLaren et al., 2018) and suggestion regarding the application of these (Wiig et al., 2019), it is interesting to see the decrease in differences with increased relationships (table 4.12, figure 4.5). For TDC/sRPE ratio, it is likely that the increase in meso 5 is influenced by a greater TDC and a decrease in sRPE in the respective meso compared to the other, discussed in chapter 5.2. Furthermore, the decreased sRPE in meso 5 is also likely a dependent factor for the increased PL™/sRPE ratio. In regard to the decreased differences in sRPE ratios compared to the RPE ratios, it is therefore likely that the duration is adjusted accordingly with the intensity, as the gross TL is more monotonous. However, the model presented rely on consistent individual characteristics throughout the competition phase, which is not assessed in the study design. It is clear that more research is needed to understand how the relationship between internal response and elicited E-TL is variated throughout the competition phase.

5.4 Limitations

5.4.1 Subjects, training sessions and match play

Even though the players participating in this thesis play in the Norwegian premier league, generalizing to other studies must be done with caution, as questions arise when comparing the competitional level and physical demands in different leagues. Moreover, different national leagues may have different historical, traditional and cultural approaches to the periodization of training. Indeed, this study gives insight in the periodization strategies in one particular club with their specific strategies. However, it should be considered whether the results can be generalized to other clubs competing in the same league, as different coaches may not have the same approaches regarding periodization and football philosophy. Nonetheless, the thesis did not intervene with any aspects of the normal training, match and match preparation for both club and players to ensure that the results could be as practically applicable and realistic as possible. The study therefore provides insight into one periodized approach rather than advocating a replicable methodology.

The fact that match data were not observed and solely exported post-match play could potentially cause biased results. Potentially, benching players in the software and double checking with the match report available on the clubs' official web site may have caused inaccurate time points in which players were subbed on/off. Furthermore, the thesis did not have control over any potential sudden disturbances that may have occurred during match play. Thus, there is potential overestimations in regard to absolute match load variables, and potential underestimations in regard to intensity variables derived from match play in this study. However, variables reported in the thesis falls within the range of previous research regarding match demands (Di Salvo et al., 2007; Malone et al., 2015)

The choice to exclude MD-1 in the thesis was taken in accordance with the club's staff together with previous findings in the literature, showing a clear decrease in TL prior to match play. Communication with the club's staff revealed planned decreases in TL and a training content focusing on tactical approaches (e.g. set pieces) preceding match play to avoid accumulation of fatigue. However, the exclusion possibly impacts certain results regarding average TL within microcycles. Furthermore, the increased HSRD and SPRINT preceding match play is contrary to previous research, and if the communication with the club is true, a possible tapering in these variables would likely be present in this thesis as well, if MD-1 was included. Nonetheless, this thesis fails to report tapering strategies in HSRD and SPRINT variables preceding match play.

5.4.2 Methodological limitations

Despite the total number of observations throughout the competition phase, the small number of subjects (n=10) raised some problems. Firstly, position-specific statistical inferences were excluded from the study. Hence, to valid results regarding differences in TL, the thesis focused on full-team differences. It is well documented in the literature that different positions demand different loads. For instance, Owen et al. (2017) reported that TL differences between positions occur due to the specific roll every position have, especially regarding distance covered in different speed zones. Briefly, wide players (e.g. full backs and wide midfielders) have been reported to cover greater distances at higher speed in comparison to players central on the pitch (e.g. central defenders and central midfielders). Thus, this study fails to report positional differences, and future studies with few subjects should potentially focus on classifying players into wide and central players. Furthermore, the inclusion criteria used in this thesis (observations in minimum 75% of all training sessions and simultaneously have observations from 5 games) excluded 13 players. Certainly, inclusion criteria with less restriction could potentially present position-specific demands. However, the criterion in this thesis was selected to ensure homogeneity of the subjects, reduce confounding factors, and increase the likelihood of finding a true difference between training sessions and mesocycles. Thus, the inclusion criteria optimize the internal and external validity of the study.

Additionally, the small number of subjects in this thesis may also have caused implications regarding statistical errors (Batterham & Hopkins, 2006). Moreover, previous studies regarding TL quantification in team sports have used statistical tests for significance checking, and thus making definite statements. With the small number of subjects in this thesis, definite statements could lead to type 1 or type 2 errors, and the statistical inferences used gives only probabilities. Moreover, as the inclusion criteria for #SATS and HDOP were lower than recommended (Malone et al., 2017), GPS derived results should be interpreted with caution.

Due to limited validity and reliability regarding rapid spontaneous changes in speed uniquely derived from GPS (Akenhead et al., 2014), the examination of these variables was excluded. However, more recent devices make it possible to quantify TL derived from acceleration, deceleration and change of directions with inertial measurement units (Luteberget, Holme, & Spencer, 2018), and thus suggesting future research to examine TL derived from these units.

The thesis' classification of speed zones and the lack of individualized speed zones may impact the results, as the lack of consistent and/or individualized speed zones across studies has been mentioned to limit time-motion and microsensor studies (Akenhead et al., 2016; Dellaserra, Gao, & Ransdell, 2014). Future research should focus on the best approach to individualize speed zones, or if not, focus on the best "one size fits all" threshold for each speed zone. Moreover, the devices in which variables were measured has shown to have a higher CV when the speed is augmented, suggesting a poor validity when examining distance covered at speeds above 5.56 $m \cdot s^{-1}$ (Rampinini et al., 2015). SPRINT results from this thesis should therefore be interpreted with caution.

Although the entire competitive season was observed, only four mesocycles were included in the thesis. The study excluded meso 1 and 2 due to < 3 GWs observed, which specifically was due to a high frequency of matches in the national cup being played mid-week in these mesocycles. Therefore, the cup matches resulted in GWs containing > 1 match and hence, abnormalities within GWs occurred. Firstly, previous research has shown differences in TL patterns during GWs containing > 1 match (Anderson et al., 2016). Thus, including the corresponding GWs would most likely reduce the TL values in the mesocycles to compensate for a greater match load. Secondly, an inclusion of mesocycles containing < 3 GWs could potentially cause biased results, as the mean TL in each GWs could affect the mean of the meso TL values with a greater magnitude. Both Oliveira et al. (2019) and Malone et al. (2015) observed a greater TL in the first mesocycle, likely because of coaches still having some emphasis on physical conditioning derived from pre-season. Hence, the results derived from the thesis may therefore not be equivalent if the other mesocycles were included. Another limitation to this study relates to one of the difficulties when using applied research, which was the fact that only 17 GWs were included, since the match schedule and coaching decisions about the structure of the microcycle could not be controlled by the researchers.

Lastly, the benching and export in 60 second time intervals from the Openfield software created intensity variables which was dependent on the time in which training started. This may have caused biased values regarding intensity variables, as every minute followed the same timeframe as the second in which training started. It is suggested that future studies should export RAW files with a frequency that corresponds with the specifications from the devices (in this case 10Hz GPS and 100Hz accelerometer) to create a rolling average.

5.5 Practical applications

Present findings give important and novel information relating to the TL employed by an elite Norwegian premier league team. Furthermore, it gives insight in one of many individual coaching strategies on TL employment. Moreover, results from this study can give coaches, practitioners and researchers insight in how TL and intensity varies within microcycles and throughout the competition phase. It provides further evidence of the value of measuring a combination of I-TL and several E-TL variables to fully evaluate the patterns observed both on microcycle and mesocycle levels. For coaches and practitioners, the findings generate both relative and absolute reference TL values for elite level that can be considered when planning training sessions. In addition, findings within microcycles indicate an increase in speed derived variables preceding match play, which is contrary to the literature. Finally, in regard to present findings, duration seems to be the component that varies the most throughout the competition phase, which directly affects other variables. Nonetheless, the results are up to coaches to further interpret, as other factors than physical capacities may be more important to overall football performance.

5.5.1 Direction for future studies

Future studies should focus on expressing TL measures in relation to match play. As there is a lack of individualized speed thresholds, the expression of relative TL may be a much better and valuable way of managing and evaluating the players periodization, as it is more sensitive to an individual compared to absolute demands. Moreover, future studies should examine the relationship between internal response and external work even further, and possibly examine adaptions and/or differences over a sufficient time period, to optimize periodization. Furthermore, this study supports the suggestions made by Wiig et al. (2019) regarding the need for a comprehensive reliability study to investigate the potential reasons for the poor reliability of sRPE in response to E-TL variables. The current study is unable to provide “optimal” TL values and their association with fatigue without undertaking other factors such as physiological testing and injury records. Hence, future research should try to establish how different external load variables and their associated internal markers relates to overall performance.

Lastly, future research should also attempt to better contextualize training loads, so practitioners can visualize the specific physical demands of different exercises within microcycles as well as throughout the competition phase.

6. Conclusion

In this study, differences in measured TL and intensity within microcycles and between mesocycles were examined throughout the competition phase in an elite Norwegian premier league football team. Present findings show that MD produces the greatest TL and intensity within microcycles. Moreover, day-to-day differences in measured TL and intensity within microcycles were observed, as different days stimulate different TL and intensity variables. Specifically, decreases are observed preceding MD, suggesting a tapering strategy to increase match performance. However, in terms of HSRD and SPRINT, values increase as match day approaches, and the possible accumulation of fatigue induced from these variables in relation to a decrease in other TL variables requires further investigation.

Present findings indicate differences in measured TL and intensity in different mesocycles throughout the competition phase. Specifically, a decrease in HSRD and SPRINT were observed in the last mesocycle compared to the other mesocycles. Moreover, a greater TDC and TDC·min^{-1} were observed in meso 5 despite lower RPE and sRPE values compared to the other mesocycles. Furthermore, meso 3 produced the lowest intensity for both TDC·min^{-1} and PL™·min^{-1}. However, this was not the case for their associated TL variables (TDC and PL™. In addition, TDC·min^{-1} had the most differences throughout the competition phase, suggesting that the fewer differences in the associated TL variable (TDC) is caused by a variation in session duration.

Within microcycles, differences in the I-TL – E-TL relationship were observed, as different training sessions produced different values. For sRPE-dependent ratios, similar values to match play were observed on MD-2, suggesting it be a coaching strategy to have a match specific load ratio when MD approaches. When comparing mesocycles, differences were mostly observed on RPE-dependent ratios, suggesting the fewer differences in sRPE ratios to be due to an accordingly adjusted duration. However, the poor reliability of sRPE and RPE makes generalization limited, and further investigation is needed to see how the pattern between the I-TL – E-TL relationship pattern varies throughout the competition phase.

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Abbreviations

#SATS	number of satellites
AT	Attackers
AU	Arbitrary unit
CI	Confidence internal
CV	Coefficient of variation
DF	Defenders
E-TL	External training load
ES	Effect Size
GNSS	Global navigation satellites systems
GPS	Global Positioning system
GW	Game week
HDOP	Horizontal dilution of precision
HSRD	High-speed running distance (distance covered >20 $km \cdot h^{-1}$)
I-TL	Internal training load
ICC	Intraclass Correlation Coefficient
MBI	Magnitude based inferences
MD	Match day
MD-1	Match day – 1
MD-2	Match day – 2
MD-3	Match day – 3
MD-4	Match day – 4
MD+1	Match day + 1
MD+2	Match day + 2
Meso	Mesocycle
MF	Midfielders

PL™	PlayerLoad™
PL™·min^{-1}	PlayerLoad™ per minute
RPE	Rate of perceived exertion
SD	Standard deviation
SEM	Standard error of measurement
SPRINT	Sprint distance (distance covered >25 km·h^{-1})
sRPE	Session rating of perceived exertion
SSG	Small-sided games
TDC	Total distance covered
TDC·min^{-1}	Distance per minute
TEM	Typical error of measurement
TL	Training load

7. Appendix

I. Positional differences and differences in TL variables within microcycles

II. Positional differences and differences in the I-TL – E-TL relationship variables within microcycles

III. Positional differences and differences in TL variables throughout the competition phase

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		MD-4	MD-3	MD-2	MD	
DF (n = 4)	TDC (m)	4402.89 ± 450.92	5438.71 ± 401.88	3633.70 ± 132.05	10599.18 ± 841.38	
	TDC·min^{-1} (m)	76.78 ± 7.52	89.50 ± 7.66	74.33 ± 3.70	105.73 ± 9.88	
	HSRD (m)	91.26 ± 39.26	211.92 ± 96.20	219.79 ± 62.00	675.32 ± 286.19	
	Sprint (m)	12.12 ± 8.06	39.98 ± 22.61	64.34 ± 26.14	202.33 ± 119.82	
	PL™ (AU)	513.07 ± 27.21	566.19 ± 28.78	369.57 ± 3.92	991.45 ± 63.30	
	PL™·min^{-1} (AU)	9.40 ± 0.53	9.52 ± 0.53	7.74 ± 0.11	9.87 ± 0.76	
	RPE (AU)	6.49 ± 0.47	5.44 ± 0.28	3.87 ± 0.14	8.34 ± 0.36	
	sRPE (AU)	545.94 ± 46.99	462.39 ± 28.51	278.31 ± 12.55	844.51 ± 33.72	
MF (n = 4)	TDC (m)	4457.07 ± 351.09	5427.57 ± 410.63	3692.97 ± 439.73	10919.43 ± 368.78	
	TDC·min^{-1} (m)	78.29 ± 6.35	89.78 ± 5.15	71.07 ± 3.35	115.33 ± 5.99	**DF
	HSRD (m)	100.89 ± 37.46	228.81 ± 111.14	224.46 ± 80.25	714.02 ± 292.69	
	Sprint (m)	10.51 ± 9.70	45.53 ± 45.19	59.27 ± 10.74	162.96 ± 110.25	
	PL™ (AU)	518.53 ± 43.29	559.48 ± 66.08	364.01 ± 40.48	1023.10 ± 41.53	
	PL™·min^{-1} (AU)	9.67 ± 0.92	9.54 ± 1.02	7.78 ± 0.85	10.81 ± 0.82	**DF
	RPE (n=3) (AU)	6.27 ± 0.48	5.49 ± 0.54	3.96 ± 0.13	8.37 ± 0.15	
	sRPE (n=3) (AU)	518.18 ± 38.42	469.85 ± 53.15	287.55 ± 16.69	786.40 ± 48.03	
AT (n = 2)	TDC (m)	4013.56 ± 73.33	4926.30 ± 68.41	3523.92 ± 222.45	10309.77 ± 219.73	
	TDC·min^{-1} (m)	72.99 ± 2.42	84.90 ± 1.80	70.67 ± 5.04	112.30 ± 5.50	
	HSRD (m)	54.46 ± 20.83	199.41 ± 32.60	217.99 ± 42.24	739.88 ± 330.83	
	Sprint (m)	6.62 ± 7.83	38.45 ± 12.47	59.80 ± 17.61	185.92 ± 152.49	
	PL™ (AU)	445.53 ± 12.64	482.04 ± 9.84	354.35 ± 32.67	928.58 ± 1.59	
	PL™·min^{-1} (AU)	8.59 ± 0.42	8.50 ± 0.16	7.25 ± 0.66	10.13 ± 0.75	
	RPE (AU)	6.60 ± 0.31	5.54 ± 0.02	4.29 ± 0.49	8.875 ± 0.17	
	sRPE (AU)	551.52 ± 19.88	479.93 ± 1.31	305.72 ± 41.59	837.75 ± 92.27	

Table 7.2: table appendix 2 - *Positional differences and within-position differences in the relationship between the subjects' self-reported internal training load and the external load elicited within microcycles. Data is presented as the mean ± SD for each ratio. Effect size (ES) between positions is indicated by the stated symbols to the right of the column in which the respective TL variable is shown and are marked with position name. Only ES with a substantial difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: MD = match day. MD- = Days in proximity to match day. DF = defenders. MF = midfielders. AT = attackers. N = number of subjects. TDC = total distance covered. RPE = Rating of perceived exertion. PL™ = PlayerLoad™. sRPE = session rating of perceived exertion. AU = arbitrary unit.*

		MD-4	MD-3	MD-2	MD
DF	TDC/RPE (AU)	725.75 ± 88.68	1046.16 ± 31.21	987.20 ± 73.41	1275.21 ± 75.77
(n=4)	PL™/RPE (AU)	85.12 ± 7.52	108.78 ± 2.15	100.71 ± 4.73	119.73 ± 9.20
	TDC/sRPE (AU)	9.57 ± 1.14	12.34 ± 0.32	15.04 ± 1.13	14.17 ± 0.84
	PL™/sRPE (AU)	1.12 ± 0.12	1.28 ± 0.03	1.53 ± 0.07	1.33 ± 0.10
MF	TDC/RPE (AU)	744.49 ± 101.16	1110.53 ± 114.41	989.02 ± 189.12	1316.42 ± 24.19
(n=3)	PL™/RPE (AU)	89.02 ± 13.68	117.61 ± 13.99	104.93 ± 20.10	127.47 ± 7.91
	TDC/sRPE (AU)	9.84 ± 1.33	13.07 ± 1.48	15.13 ± 2.95	14.63 ± 0.27
	PL™/sRPE (AU)	1.18 ± 0.18	1.38 ± 0.18	1.60 ± 0.31	1.42 ± 0.09
AT	TDC/RPE (AU)	631.57 ± 19.82	931.75 ± 27.11	890.08 ± 47.00	1166.66 ± 1.26
(n=2)	PL™/RPE (AU)	70.44 ± 1.62	91.24 ± 3.38	89.24 ± 2.58	105.39 ± 1.87
	TDC/sRPE (AU)	8.34 ± 0.28	10.99 ± 0.23	13.55 ± 0.67	15.00 ± 2.09
	PL™/sRPE (AU)	0.93 ± 0.02	1.07 ± 0.03	1.36 ± 0.03	1.36 ± 0.18

Table 7.3: table appendix 3 - *Differences in training load across the competitive phase. divided into four mesocycles. Data are presented as mean ± SD and represent the average training load every position elicited during each training sessions in the predetermined mesocycles. Effect size (ES) between positions is indicated by the stated symbols to the right of the column in which the respective TL variable is shown. Only ES with a substantial difference (> 75%) are shown. * small, ** moderate, *** large, **** very large Abbreviations: DF = defenders. MF = midfielders. AT = attackers. TDC = Total distance covered. Min = minute. HSRD = high-speed running distance. Sprint = sprint distance. PL™ = PlayerLoad. RPE = rating of perceived exertion. sRPE = session rating of perceived exertion. M = meters. AU = arbitrary unit*

		Mesocycle 3	Mesocycle 4	Mesocycle 5	Mesocycle 6
DF	TDC (m)	4436.67 ± 356.13	4402.93 ± 243.24	4580.78 ± 439.38	4315.59 ± 335.74
(n=4)	TDC·min^{-1} (m)	64.39 ± 4.74	82.46 ± 6.07	83.85 ± 7.11	82.02 ± 7.71
	HSRD (m)	197.44 ± 77.47	179.36 ± 54.78	187.87 ± 85.29	131.18 ± 56.01
	Sprint (m)	49.95 ± 20.92	41.86 ± 18.166	41.99 ± 22.79	19.58 ± 9.41
	PL™ (AU)	492.65 ± 21.09	478.41 ± 14.12	479.11 ± 34.85	455.47 ± 22.10
	PL™·min^{-1} (AU)	8.22 ± 0.28	9.18 ± 0.41	8.72 ± 0.54	8.64 ± 0.68
	RPE (AU)	5.29 ± 0.58	5.65 ± 0.32	5.06 ± 0.29	5.43 ± 0.36
	sRPE (AU)	459.08 ± 50.92	437.18 ± 23.65	395.63 ± 26.38	419.44 ± 37.06
MF	TDC (m)	4280.37 ± 244.50	4314.89 ± 602.14	4915.39 ± 344.44 **	4366.75 ± 721.25
(n=4)	TDC·min^{-1} (m)	58.20 ± 6.64	80.62 ± 9.27	91.71 ± 6.72 **	84.91 ± 9.25
	HSRD (m)	160.70 ± 40.64	162.08 ± 66.93	202.01 ± 105.99	159.15 ± 107.30
	Sprint (m)	40.16 ± 14.98	30.03 ± 20.53	43.44 ± 37.31	30.72 ± 39.14
	PL™ (AU)	483.62 ± 16.98	471.76 ± 73.77	515.49 ± 54.86 **	463.35 ± 85.96
	PL™·min^{-1} (AU)	8.29 ± 0.80	9.09 ± 1.29	9.51 ± 1.03 **	8.97 ± 1.10
	RPE (n=3) (AU)	4.85 ± 0.83	5.32 ± 0.55	5.06 ± 1.25	5.57 ± 0.50
	sRPE (n=3) (AU)	407.96 ± 69.52	411.03 ± 6.02	404.33 ± 106.45	432.76 ± 38.32
AT	TDC (m)	4299.66 ± 69.84	3949.82 ± 160.53	3878.95 ± 149.11	4228.12 ± 168.45
(n=2)	TDC·min^{-1} (m)	62.18 ± 0.21	76.18 ± 6.28	78.73 ± 2.01	78.89 ± 2.53
	HSRD (m)	179.47 ± 2.77	161.03 ± 35.73	172.40 ± 23.98	134.50 ± 45.69
	Sprint (m)	39.79 ± 1.34	39.08 ± 12.38	38.81 ± 15.42	24.64 ± 18.36
	PL™ (AU)	454.70 ± 8.38	401.67 ± 18.26	385.84 ± 12.29	429.40 ± 8.60
	PL™·min^{-1} (AU)	7.45 ± 0.20	8.09 ± 0.62	7,85 ± 0.03	7.99 ± 0.12
	RPE (AU)	5.11 ± 0.16	5.34 ± 0.59	5.00 ± 0.00	6.31 ± 0.12
	sRPE (AU)	450.53 ± 10.69	401.03 ± 33.38	378.03 ± 29.03	486.19 ± 12.06

Table 7.4: table appendix 4 - *Position specific differences in the relationship between internal and external training load variables throughout the competitive phase of the season. divided into 4 mesocycles. Data are presented as mean ± SD of the ratio between the external and internal variable. Effect size (ES) between positions is indicated by the stated symbols to the right of the column in which the respective TL variable is shown and are marked with position name. Only ES with a substantial difference (> 75%) are shown. * small, ** moderate, *** large, **** very large. Abbreviations: DF = defenders. MF = midfielders. AT = attackers. N = number of subjects. TDC = total distance covered. RPE = rating of perceived exertion. PL™ = PlayerLoad™. sRPE = session rating of perceived exertion. AU = arbitrary unit*

		Mesocycle 3	Mesocycle 4	Mesocycle 5	Mesocycle 6
DF	TDC/RPE (AU)	943.97 ± 95.32	845.57 ± 76.20	989.74 ± 65.07	817.31 ± 57.36
(n=4)	PL™/RPE (AU)	103.50 ± 8.66	92.36 ± 8.27	103.89 ± 7.37	85.78 ± 2.96
	TDC/sRPE (AU)	12.05 ± 2.03	11.34 ± 1.05	13.35 ± 0.80	11.22 ± 0.86
	PL™/sRPE (AU)	1.38 ± 0.10	1.24 ± 0.11	1.40 ± 0.09	1.18 ± 0.03
MF	TDC/RPE (AU)	906.47 ± 215.44	904.58 ± 113.52	1120.41 ± 366.74	851.21 ± 202.32
(n=3)	PL™/RPE (AU)	105.58 ± 28.82	99.68 ± 14.67	120.28 ± 43.44	91.29 ± 21.51
	TDC/sRPE (AU)	12.10 ± 2.95	11.90 ± 1.82	15.32 ± 4.86	11.72 ± 3.03
	PL™/sRPE (AU)	1.41 ± 0.40	1.31 ± 0.22	1.64 ± 0.58	1.26 ± 0.32
AT	TDC/RPE (AU)	922.04 ± 35.73	806.07 ± 68.59	806.70 ± 128.02	704.61 ± 60.17
(n=2)	PL™/RPE (AU)	95.66 ± 4.90	81.71 ± 7.25	81.01 ± 11.97	71.51 ± 5.01
	TDC/sRPE (AU)	12.35 ± 0.47	10.67 ± 0.96	10.97 ± 1.62	9.66 ± 0.94
	PL™/sRPE (AU)	1.28 ± 0.07	1.08 ± 0.10	1.10 ± 0.15	0.98 ± 0.09

Appendix V – Letter of consent

NORGES IDRETTSHØGSKOLE

Forespørsel om deltakelse i forskningsprosjektet Monitorering av fysisk belastning gjennom en fotballssong for norske fotballspillere

Dette er et spørsmål til deg om å delta i en forskningsprosjekt for å undersøke variasjoner i trenings- og kampbelastning gjennom en sesong i fotball. I de senere år har det blitt mer vanlig å monitorere fotballspillere ved hjelp av GPS, både på trening og i kamper. Kunnskap om den fysiske belastningen i ulike øvelser, og over lengre tid – som f.eks. en sesong, kan være til hjelp for spillere, trenere og andre i støtteapparatet for å holde oversikt over belastning, skaderisiko og prestasjon. Det har i de siste årene kommet frem mye kunnskap om treningsbelastning og kampbelastning gjennom slike undersøkelser, men få studier har sett på variasjoner i trenings- og kampbelastning gjennom en hel fotballsesong. Det er flere faktorer som spiller inn på den fysiske belastingen som en fotballspiller blir utsatt for, blant annet har spillerposisjon en stor betydning. Det er derfor av interesse for dette prosjektet å se på belastningsdata for de ulike spillerposisjonene.

Vi søker til denne studien mannlige fotballspillere på elitenivå i Norge. Om du har lest denne informasjonen og ønsker å delta som forsøksperson ber vi deg skrive under og returnere den siste siden til oss. Du kan når som helst i etterkant trekke deg fra studien uten å oppgi grunn. Torvald Berthelsen (Tlf: 92058589, epost: torvald_bertelsen@hotmail.com) og Kjetil Rønneberg (Tlf: 92636736, og epost: kjetil_ronneberg@hotmail.com) vil gjennomføre monitoreringen av trening og kamper i prosjektet. Ansvarlig for studien er Norges idrettshøgskole og prosjektleder er førsteamanuensis Matt Spencer.

Hva innebærer prosjektet?

I dette prosjektet vil vi måle belastning (ved hjelp av GPS og RPE) på treninger og kamp gjennom hele sesongen. For å delta i prosjektet så krever det at du møter opp på treninger og kamper med laget, slik som trener for laget beskriver. Metodene for innsamling av data er de samme som dere til daglig bruker i klubben, og datainnsamlingen vil derfor ikke vike fra din vanlige treningshverdag. Prosjektet vil registrere din alder, høyde og spillerposisjon, i tillegg til data som samles inn i trening og kamper. Data vil kun samles inn i sammenheng med klubbens treninger og kamper, og prosjektet vil derfor ikke kreve mer oppmøter en det som normalt kreves av deg som fotballspiller.

Mulige fordeler og ulemper

Studien kan hjelpe til å øke kunnskap rundt belastning og treningsintensitet gjennom sesongen vil kunne være med å utvikle kunnskapen rundt idretten, som igjen kan være gunstig for trenere og spillere, både med tanke på prestasjon og belastning i trening. Som deltaker i studien kan du dermed være med å øke kunnskapen rundt fotball, belastning og monitorering.

Deltakelse i prosjektet vil kreve en del tid og oppmerksomhet, og det kreves at du som forsøksperson er tilstede på treninger og kampdager. Trening og kamper kan kreve maksimal innsats, og vil oppleves anstrengende. Dette kan medføre noe ubehag, men ikke mer en dere som idrettsutøvere er vandt med gjennom deres daglige trening. Studien krever at du som spiller har på deg måleutstyr i trening og kamp, som noen kan synes er ubehagelig.

Frivillig deltakelse og mulighet for å trekke sitt samtykke

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte Torvald Berthelsen (Tlf: 92058589, epost: torvald_bertelsen@hotmail.com)

Hva skjer med informasjonen om deg?

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.
Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til opplysninger gjennom en navneliste. Dette betyr at denne informasjonen er avidentifisert. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Informasjon om deg vil bli oppbevart i 5 år etter prosjektslutt for etterprøvbarhet og kontroll før de slettes.

Forsikring

Alle deltakerne er forsikret ved at NIH som statlig institusjon er selvassurandør.

Godkjenning

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS (saksnummer fylles ut når det er klart) og godkjent av intern etisk komite ved Norges idrettshøgskole (saksnummer fylles ut når det er klart)

Samtykke til deltakelse i prosjektet

Jeg har mottatt informasjon om studien, og er villig til å delta

……………………………………………………………………………………………...

Sted og dato   Deltakers signatur

…………………………………………...

Deltakers navn med trykte bokstaver

Appendix VI – approval of data storage

Matthew Spencer
Postboks 4014
0806 OSLO

Vår dato: 17.04.2018	Vår ref: 59666 / 3 / EPA	Deres dato:	Deres ref:

Tilrådning fra NSD Personvernombudet for forskning § 7-27

Personvernombudet for forskning viser til meldeskjema mottatt 07.03.2018 for prosjektet:

59666	*Monitorering av fysisk belastning gjennom en fotballsesong for norske elitespillere*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Matthew Spencer*
Student	*Kjetil Rønneberg*

Vurdering

Etter gjennomgang av opplysningene i meldeskjemaet og øvrig dokumentasjon finner vi at prosjektet er unntatt konsesjonsplikt og at personopplysningene som blir samlet inn i dette prosjektet er regulert av § 7-27 i personopplysningsforskriften. På den neste siden er vår vurdering av prosjektopplegget slik det er meldt til oss. Du kan nå gå i gang med å behandle personopplysninger.

Vilkår for vår anbefaling

Vår anbefaling forutsetter at du gjennomfører prosjektet i tråd med:
- opplysningene gitt i meldeskjemaet og øvrig dokumentasjon
- vår prosjektvurdering, se side 2
- eventuell korrespondanse med oss

Meld fra hvis du gjør vesentlige endringer i prosjektet

Dersom prosjektet endrer seg, kan det være nødvendig å sende inn endringsmelding. På våre nettsider finner du svar på hvilke endringer du må melde, samt endringsskjema.

Opplysninger om prosjektet blir lagt ut på våre nettsider og i Meldingsarkivet

Vi har lagt ut opplysninger om prosjektet på nettsidene våre. Alle våre institusjoner har også tilgang til egne prosjekter i Meldingsarkivet.

Vi tar kontakt om status for behandling av personopplysninger ved prosjektslutt

Ved prosjektslutt 31.12.2018 vil vi ta kontakt for å avklare status for behandlingen av personopplysninger.

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

NSD – Norsk senter for forskningsdata AS | Harald Hårfagres gate 29 | Tel: +47-55 58 21 17 | nsd@nsd.no | Org.nr. 985 321 884
NSD – Norwegian Centre for Research Data | NO-5007 Bergen, NORWAY | Faks: +47-55 58 96 50 | www.nsd.no

Se våre nettsider eller ta kontakt dersom du har spørsmål. Vi ønsker lykke til med prosjektet!

Vennlig hilsen

Marianne Høgetveit Myhren

Eva J. B. Payne

Kontaktperson: Eva J. B. Payne tlf: 55 58 27 97 / eva.payne@nsd.no
Vedlegg: Prosjektvurdering
Kopi: Kjetil Rønneberg, kjetil_ronneberg@hotmail.com

Appendix VII – approval by the local ethics committee

Matt Spencer
Seksjon for fysisk prestasjonsevne

OSLO 20. mars 2018

Søknad 50-200318 – Monitonering av fysisk belastning gjennom en fotballsesong for norske elitespillere

Vi viser til søknad, prosjektbeskrivelse, informasjonsskriv og innsendt søknad til NSD.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt konkludert med følgende:

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at prosjektet er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *At NSD godkjenner prosjektet og at eventuelle vilkår fra NSD følge*

Vi gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Med vennlig hilsen
Professor Sigmund Loland
Leder, Etisk komite, Norges idrettshøgskole

NIH NORGES IDRETTSHØGSKOLE

Besøksadresse: Sognsveien 220, Oslo
Postadresse: Pb 4014 Ullevål Stadion, 0806 Oslo
Telefon: +47 23 26 20 00, postmottak@nih.no
www.nih.no