Summary

Load, Intensity and Performance in Professional Road Cycling
Professional road cycling is a high demanding sport, where cyclists depending on their age, role in the team, specialty and gender, race 40 up to 100 days in competition. A significant number of races are multiple stage-races, which could mean up to 10 consecutive race-days without a rest day. In such a high demanding sport, the ability to sustain high load and intensity demands is one of the determinants to be able to perform in professional cycling. Understanding those load and intensity demands in professional male and female races could help coaches and sport scientist to establish training goals. Training programs contain a certain amount of Training load (TL) which can be distinguished in external and internal TL. Internal load rather than the external load imposed to the athlete determines the training adaptations. Therefore, understanding the relationship between external and internal load could be of high value. Load matched with a sufficient recovery would lead to a positive adaptation, however when load and recovery are in disbalance this could lead to a negative adaptation. Therefore, this thesis focused on the load and intensity demands in professional male and female cyclists and the relation between internal and external TL. In addition, the association between load and injuries and illnesses is investigated.

In Chapter 2 the load and intensity demands and the performances from a cyclist competing for the General Classification (GC) during multiple Grand Tours (GTs) are described. From 4 different GTs (i.e. the Vuelta a España 2015, the Giro d’Italia 2017, the Giro d’Italia 2018 and the Tour de France 2018) Power Output (PO) was collected and the load and intensity demands and performance were analyzed. The cyclists finished 6th, 1st, 2nd and 2nd in the analyzed GTs and therefore the presented data was a good representation for the demands in the fight for a GT victory. With exception of an absolute lower time spent in PO zone 5 during the Giro d’Italia 2017, no differences were found between the 4 GTs. The average relative PO on the key mountains for the 4 GT was 5.9 W·kg⁻¹ and varied from 5.7 W·kg⁻¹ at the Giro d’Italia 2017 up to 6.0 W·kg⁻¹ at the Giro d’Italia 2018. Further it was investigated by a stepwise multiple regression analysis, that climbing performance is affected by mountain characteristics (i.e. duration and steepness) and by short-term fatigue, measured by either total elevation gain, kJ spent·km⁻¹ or TSS·km⁻¹ before the key mountain. Mountain characteristics and short-term fatigue explained 86% of the variance of the relative PO on the key mountains, while
volume (distance and duration) and load measurements (kJ spent and TSS) before the key mountain did not significantly influence climbing performance. The results suggest that the GC contender does not get fatigued by endurance before the key mountain but rather by the intensity before the key mountain.

In **Chapter 3** the load and intensity in professional cycling races were investigated and the differences between men and women were highlighted. During 4 consecutive years, data (PO, Rate of Perceived Exertion (RPE), Hear Rate (HR)) was collected from men’s (n= 3025) and women’s (n= 677) during professional races, from which load and intensity characteristic were calculated and analyzed. It was hypothesized that the difference between race regulations between men and women would result in different load and intensity demands. In agreement with this hypothesis, *large to very large* higher values were observed for distance, duration, total work and mean PO in men’s races compared to women’s professional races. Although load values expressed as TSS and eTRIMP were *small* higher in men’s professional races. Surprisingly time spent in the high intensity zones was *largely* higher in women’s races and load metrics expressed per kilometer (kJ spent·km⁻¹, sRPE·km⁻¹, eTRIMP·km⁻¹ and TSS·km⁻¹) were *large to very largely* higher in women’s races. It was concluded that load and intensity demands differ between men’s and women’s professional cycling races. Subsequently it was argued that different trainings goals should be in place between men and women professional cyclists.

Therefore, in **Chapter 4** we investigated the load and intensity from training sessions in professional cyclists and highlighted the differences between the training strategies of men’s and women’s cyclists. From 9 822 training files we analyzed load and intensity measures. Similar to the differences between men’s and women’s race demands, we found *small to large* higher values for distance, duration, kJ spent and (relative) mean PO in men’s training compared to women’s training. In contrast to races *trivial* differences were found between TSS and eTRIMP in men and women’s training sessions. While load values expressed per kilometer were *moderate* higher in women’s training sessions compared to men’s training sessions. We concluded that professional women’s cyclists compensate their lower training volume, with higher intensity’s compared to professional men’s cyclists. It seems that different training strategies are applied between men’s
and women’s professional cyclist. Although differences between men’s and women’s cyclists are larger in races compared to the differences between men’s and women’s cyclists in training.

The purpose of Chapter 5 was to investigate the relationship between various load measures during training, racing and Time Trials (TTs). From a large data set (11,655 sessions) kJ spent, luTRIMP, sRPE and TSS were calculated and correlations between the various training load measurements were made from session in races, training and TTs. The correlation between various TL measures was almost perfect or very large. Although a slightly weaker correlation was found during races, it was suggested that parameters which influence internal TL measures are less controlled in races compared to training and therefore have a weaker correlation with external measures of TL. Furthermore, a significant different slope was found between the correlation of TSS and the other measures of TL in races and training. This results in that the differences between TSS in training and races is ~120%, while this differences for the other TL measures is ~70%.

To understand those differences between the various TL measures and TSS, we investigated in Chapter 6, if exercise intensity could be the reason for those differences. Exercise intensity is highly important in calculating TSS, as there is a quadratic relationship between exercise intensity and TSS. Firstly, we investigated the differences between the exercise intensity in training and racing. Secondly, we investigated how exercise intensity influences various TL measures. We concluded that races were with a higher exercise intensity compared to training. Further, TSS is significantly influenced by exercise intensity in contrast to luTRIMP and sRPE. Thus, a session with an equal amount of kJ spent, but with a low or high exercise intensity will result in a different TSS score. This is in contrast with the other load measures which are not influences by exercise intensity.

In Chapter 7 we focused on the possible negative adaption when TL and recovery are in disbalance. We investigated if TL and TL models have an association with the likelihood of injuries and illnesses. From 22 seasons, sRPE was collected and acute load (1 week), chronic load (4 weeks), together with 3 acute to chronic workload models were analyzed. Two of the workload models were based on the ratio between acute and chronic load, the difference between the two models is that in the Acute to Chronic Workload
Ratio (ACWR), the acute load is part of the chronic load. Where in the Acute to Chronic Workload_{uncoupled}, (ACWR_{uncoupled}) the acute load and chronic load are uncoupled. Further the 3\textsuperscript{th} workload model is calculated based on an Exponentially Weighted Moving Average of the ratios (EWMA). We concluded that a high acute load, a high ACWR, a high ACWR_{uncoupled} and a high EWMA are associated with a significantly higher likelihood of injury. In contrast to a high chronic load which protects against injuries. While there are no clear associations between training load and the likelihood of illnesses.

In Chapter 8 the load and intensity in training, races and GTs were compared in professional cycling. It was concluded that the load and intensity demand between training and races differ in both men and women professional cyclists. While there are no differences between the load and intensity demands measured in GTs and races. Comparing the load and intensity demands in training and races in professional men and women led to the suggestion that professional cyclists could benefit from a more polarized training approach. Further various TL measures were discussed, and it was suggested that all TL measures have their advantages and disadvantages. Therefore, it is recommended to monitor a combination of TL measures in professional cyclists, preferable a combination of internal and external measures. Monitoring a combination of load measurements ensures that there is no misleading or missing information. Furthermore, a combination of load measures could result in a tool to monitor both fatigue and fitness in professional cyclists.