Chapter 1

General introduction
During a wheelchair basketball game, an athlete has to perform optimal in their wheelchair. The interaction between wheelchair and athlete is decisive for this. A basketball sports wheelchair can be adjusted in many ways and all adjustments have a potential effect on the performance. In the search for the optimal basketball sports wheelchair and the optimal adjustment to the athlete, information about all wheelchair movements and athlete actions during a wheelchair basketball game is necessary. These wheelchair movements and athlete actions, called mobility performance, are essential to understand wheelchair basketball. Therefore, the focus of this thesis is:

1.1 Wheelchair basketball
Wheelchair basketball was first played by USA World War II veterans in 1945. Independently, in 1948 British war veterans started playing wheelchair netball at Stoke Mandeville Hospital in Great Britain. When in 1956 an USA team entered the International Stoke Mandeville Games, the forerunner of the Paralympic Games, there was a further burst of interest. In 1960, wheelchair basketball was one of the eight sports at the inaugural Paralympic Games in Rome, Italy. Nowadays, wheelchair basketball is one of the most popular Paralympic sports.

Wheelchair basketball is very similar to basketball. Most of the rules are the same to those in able bodied basketball, the basket is at equal height and the field has the same dimensions. Wheelchair basketball is a fast-paced game played by two teams of five players in a hand-rim wheelchair. Every team consists of five players and at most seven substitutes. Wheelchair basketball is open to athletes with a permanent physical impairment in the lower limb(s) which can be objectively verified. Impairments may include (lower) limb amputations, cerebral palsy and spinal cord injuries. For instance, players with severe spasms can participate in wheelchair games although they may be able to walk. Not all players in a team have the same type of impairment. Yet, to have a fair competition, teams must consist of players who, on average, have a comparable limitation due to their impairment. To assess the level of impairment, an internationally accepted classification system is used in which eight classes are defined – ranging from 1.0 to 4.5 – with 1.0 being the most limiting impairment. During a game for the five players on court the sum of classification points may not exceed 14 (43).

1.2 Performance in wheelchair basketball
In recent years, wheelchair basketball performance has improved incredibly. This is due to improvements in the physical performance and conditioning of athletes, propulsion technique, tactical awareness and substantial developments in the design and configurations of the
basketball wheelchairs (53). As can easily be understood, performance in wheelchair basketball is dependent on a lot of different aspects and most of these aspects interact with each other. For example, when the wheelchair configuration changes, the propulsion technique also changes, which in turn impacts individual game play.

Performance in wheelchair basketball can be analyzed at multiple levels (Figure 1). Winning or losing the game, is dependent on the performance of the team as a whole. Team performance is the result of all underlying elements of performance and is highly dependent on the performance of the five different active players on the field. The ability of individuals to work together productively as a team is vitally important to the success (74).

![Figure 1](image)

Figure 1. Team performance in wheelchair basketball is defined as the combined athlete performance of five athletes on the field. Individual athlete performance consists of individual game, physical and mobility performance. Focusing on mobility performance in wheelchair basketball, means focusing on the interaction between the athlete, the wheelchair and the environment.

The second level after team performance is athlete performance (Figure 1). Athlete performance is the individual performance of an athlete during a wheelchair basketball game. Individual athlete performance is also dependent on several performance aspects such as physical condition, ball skills and the interaction with their wheelchair. Athlete performance can be divided into three performance aspects: 1) physical performance; 2) game performance and 3) mobility performance.
Physical performance is the physical capacity of an athlete to perform and is often quantified in measures such as heart rate, power output, oxygen consumption and lactate level (8). The diversity of individual impairments results in a variety of physiological capabilities. As a short example of physical performance, the average heart rate during a wheelchair basketball match was 163 ± 11 beats/min and the average oxygen uptake 2.26 ± 0.06 L-min (20). Physical performance also includes the mental capacity of an athlete. The second aspect is game performance, defined as the true quality of a player’s contribution to the game in terms of scored points, offensive rebounds, blocked shots and throws completed. A commonly used method to determine game performance is the Comprehensive Basketball Grading System (11). For example, Gomez et al. (36) stated that the field-goals percentage and the free-throws rate are the most important factors in men’s games, and the field-goals percentage and offensive rebounding percentage in women’s games. Men take on average 68.6 shots per game versus 65.4 for women and the shot accuracy was for men 39.5% and for women 27.1% (100,101). Finally, mobility performance is defined as what the athlete does (or can do) with a wheelchair (54). An athlete handles the wheelchair mainly by using arms and trunk resulting in wheelchair-athlete activities such as driving forward or backward, rotating and blocking. Mobility performance in wheelchair basketball is dependent on the athlete, the wheelchair and the environment, the latter being a general term that encloses aspects like the opponents, floor surface or team composition. Athletes control their wheelchairs through physical actions that cause movements of their wheelchairs in the environment. All three aspects interact with each other continuously (Figure 1). For example, when a wheelchair setting changes, the propulsion technique of the athlete will change, leading to different actions on the field (environment). Another example is for instance the requirements of a field position that lead to certain wheelchair-athlete actions and these actions may be improved by changes in the wheelchair settings.

Systematic research is fundamental to understand wheelchair basketball performance, and its optimization at both the technical and at the individual level, as well as their interaction. The last years, much research has been done into the physical performance of wheelchair basketball athletes (37,76,107). Knowledge about physical performance can be used to e.g. improve training schemes to enhance the athlete physical performance. When focusing on game performance, the trainer’s knowledge about e.g. tactical and ball skills is very decisive. Different training methods can be used and evaluated to enhance game performance. The third aspect to improve, is the mobility performance. It takes into account the individual capacities of the athlete, the possibilities of the material, and the requirements of the environment and the continuous interaction between them. The wheelchair design, wheelchair adjustment to the athlete and driving techniques to move around in the environment, are essential for optimal results. When the wheelchair changes, its orientation to the athlete changes and, therefore, the driving technique changes. For wheelchair basketball athletes, the individual adjustment of the wheelchair to their impairment, supplemented with the requirements of the environment, is of
great importance and determines performance. For example, to throw the ball in the basket, sitting as high as possible is advantageous. However, when you sit higher, it is more difficult to deliver propulsion on the hand rim as a consequence of the larger shoulder-wheel distance, especially when you have limited trunk function. It enhances scoring opportunities, but the mobility performance is influenced. The challenge is to find the optimum in the wheelchair-athlete-environment interaction to enhance performance. So far, knowledge about the wheelchair-athlete interaction is predominantly based on daily life situations and not focused on the wheelchair basketball practice. Knowledge about the effect of wheelchair adjustments will lead to a better wheelchair-athlete interaction which improves mobility performance and, therefore, team performance. In the search for the optimal wheelchair-athlete-environment configuration, acquiring knowledge of how athletes handle their wheelchairs during matches, is essential. Therefore, the focus of this thesis is on mobility performance in wheelchair basketball.

1.3 Mobility performance in wheelchair basketball
Defining and quantifying mobility performance
Knowledge of how athletes handle their wheelchairs during matches is essential to determine mobility performance in wheelchair basketball and is lacking in current literature. To understand the important role of mobility performance to game play as well as its impact on wheelchair design and fitting for individual players, game mobility performance of elite players must be described. Information about how many times and how long players perform movements like driving forward, rotation and blocking provides insight in the requirements of a wheelchair basketball team in match play. Time-motion analysis techniques can be used to determine the time spent performing various activities and provide insight in the mobility performance during wheelchair basketball (8).

Regarding mobility performance in wheelchair basketball, research is very limited. Coutts (18) estimated that during a wheelchair basketball game, 64% of the game would be spent in propulsive actions and 36% in braking activity. However, this analysis was based on a 6 minutes exhibition game. Bloxham et al. (8) evaluated the time players spent performing various game activities during a wheelchair basketball World Cup game. Players spent almost half the game time resting (48.3%), 8.9% sprinting, 23.5% gliding, 18.2% contesting for ball possession, 0.6% sprinting with ball possession and 0.3% shooting. Unfortunately, this study was based on only six male members of the Canadian team. Furthermore, in both studies not all possible wheelchair-athlete actions were included. Besides the missing activities, like driving backward and blocks, and the very small sample size (n=6), also information about wheelchair handling is lacking. An extensive and complete time-motion analysis to define and quantify mobility performance in wheelchair basketball is necessary to get a clear and full picture of actual mobility performance during games.
Simulating mobility performance

Time-motion analyses can be used to provide insight in mobility performance during wheelchair basketball. However, extensive and complete time-motion analysis is very time-consuming. Furthermore, the results are influenced by the continuously changing environment. Each game has unique circumstances depending on, for example, the opponent, floor surface or team composition. To assess and monitor mobility performance in a controllable setting, the mobility performance during a match must be simulated. Simulation can be done in several ways. One option is laboratory-based experimentation, for example with a wheelchair ergometer or with a wheelchair on a treadmill. Another option is a more practical field-based approach. This thesis focuses entirely on the latter practical approach. A standardised field-based test founded on extensive wheelchair basketball match observations and analyses is assumed to be informative and helpful to simulate mobility performance in wheelchair basketball (38,98). An important issue to be addressed is the validity and reliability of such a field-based test in order to be able to deduce “true” improvements in mobility performance when observing performance during repeated testing (38). There are field-based tests for wheelchair court sports. However, they assess mainly other aspects of performance, such as athlete performance (heart rate and oxygen uptake), game performance (ball skills) and only limited parts of mobility performance, while they are not based on a structured reflection of the game (4,23,26,35,39,108).

A generally accepted valid and reliable mobility performance test for wheelchair basketball based on extensive game observations, is not available yet. Such a wheelchair basketball specific test can potentially be used to detect strengths and weaknesses of players in mobility performance and to monitor progress in mobility performance over time. Furthermore, a wheelchair test simulating wheelchair basketball mobility performance can be used to examine the impact of different wheelchair configurations on mobility performance (53). To allow this, the test must be sensitive to change in mobility performance when the configuration of a wheelchair is changed.

Predicting and optimizing mobility performance

Several aspects influence mobility performance and one aspect can have more effect than another one. To give direction to the many aspects that are potential ‘game changers’ or determinants of performance and its underlying hierarchy, it is useful to perform predictive analyses on basis of a wide array of potential determinants. Such a study should investigate which athlete, wheelchair and athlete-wheelchair interaction characteristics are the best predictors of mobility performance and the results can contribute to decide which characteristics should be investigated in order to optimize mobility performance in wheelchair basketball. At the moment, it is not really known which of those characteristics have the most impact on mobility performance. Slight adjustments to the way in which each characteristic is configured will affect the wheelchair propulsion and, therefore, the mobility performance (53). The majority of
investigations to wheelchair-athlete characteristics have been conducted with an extremely biased focus on aspects of mobility performance in daily life propulsion and not in a wheelchair basketball context. However, wheelchair-athlete adjustments assumed to have a significant impact on mobility performance as a whole. Mason et al. (53) recommended practical research procedures and precautions to further improve understanding of mobility performance. This enhances the possibility to make results directly applicable and usable to wheelchair basketball. The effect of wheelchair-athlete interaction settings should be measured under the most ecologically valid conditions i.e. in a standardized situation which realistically reflects mobility performance in wheelchair basketball with wheelchair basketball players of different classifications.

1.4 Research context
This thesis is the result of a unique collaboration between the knowledge institutes The Hague University of Applied Sciences, Vrije Universiteit Amsterdam, TU Delft and University of Groningen, together with professionals in sport practice from NOC*NSF, the Dutch Basketball Federation (NBB), rehabilitation centers Sophia Rehabilitation and Reade and Motion Matters. Within this research project, a second approach which focused on the technical part of wheelchair kinematics resulted in a thesis as well (82). The practice-based approach of this thesis required a multidisciplinary approach in which researchers, wheelchair technicians, coaches and athletes act together. The research questions in this program, are in general derived from “real life” situations and focus on a structural interaction between education and research within and between applied and regular universities. Being one of the conditions for funding by RAAK-PRO, the new knowledge must contribute to professional practice, education as well as to theoretical understanding of a common problem.

1.5 Thesis aim
An extensive understanding of mobility performance during wheelchair basketball is necessary. Therefore, the aims of this thesis are to define, quantify, simulate, predict and optimize mobility performance in wheelchair basketball.

In this thesis, the different aims are discussed sequentially. In Chapter 2, the athlete and wheelchair aspects related to mobility performance during matches are defined. An overview of all the wheelchair-handling activities during wheelchair basketball matches is described, with the main focus on differences between field positions and playing standard. Chapter 3 describes and quantifies to what extent mobility performance is influenced by game state (offense/defense) and ball possession and to what extent the effects of game state and/or ball possession are different for the field positions. Chapters 4 and 5 are directly focused on the development process of the wheelchair mobility performance (WMP) test. Chapter 4 describes the development, the reliability and validation process of the field-based WMP test that simulates mobility performance capacity and which closely mimics the wheelchair mobility skills required
in real wheelchair basketball matches. **Chapter 5** validates the WMP test for measuring changes in wheelchair-athlete configuration. **Chapter 6** provides insight in athlete, wheelchair, and athlete-wheelchair interaction characteristics which can predict mobility performance in wheelchair basketball and finally **Chapter 7** gives the first results of research in changing a few, of the many possible, wheelchair adjustments to (potentially) optimize mobility performance.

A summary and discussion of the general findings is presented in **Chapter 8**. Practical implications, suggestions for future research and possibilities for applications in other sports are also presented in this last chapter.