Sport and Sleep

Applied Sleep Research for Sports Science

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Preface

Sport and sleep—these are two poles like: action and rest, peak performance and paralysis. A contrast could hardly be greater. At first glance. On the second, it becomes clear that sleep and sport influence each other. One conditions the other. Therefore, it is surprising that the connection between the performances during the day and the recovery at night receives so little attention—neither in practical application fields such as competitive sports nor in the corresponding scientific research.

When considering elite sports, the waking state can be simplistically—and not entirely seriously—viewed as a temporary hyperactive catabolic phase that serves training, eating, and competition. But why do we sleep? Why has evolution produced a state in which humans are completely inactive and vulnerable? The function of sleep must be enormously important, as it has prevailed evolutionarily despite significant disadvantages—such as the inability to escape from saber-toothed tigers. Humans sleep away a third of their lives and need sleep as much as they need food and drink. Nature has left us with even more mysteries with the experience of nightly dreams. Why does our sleeping brain produce a fantasy world in which we sometimes endure bizarre adventures, not even knowing that *we* are dreaming and rarely being able to remember the contents upon waking? By the age of 40, we have spent a good three years in the "holographic deck" in our heads. And yet, the function of dreams is even more enigmatic than the function of sleep.

What does all this have to do with sports? Here are three examples: At a gymnastics training camp, young athletes practice a somersault dismount from the bar for the first time, but by the end of the practice session, they still haven't quite mastered the new element. They plan to meet again for a second training session in the afternoon. Is it worth taking a nap to consolidate what they've just learned? A girl dreams at night of throwing balls and javelins as far as possible. The next day, she goes to a student championship. Will her nocturnal "training" result in a new personal best? At the Olympic Games, a medal hopeful in swimming has an important qualifying race ahead of her. The night before the competition, the athlete can't get a wink of sleep. Will the missed sleep affect her performance? You will find answers to these questions in this book.

In the meantime, sleep is attributed a certain significance in sports, therefore a basic understanding of the topic of sleep in sports practice is desirable. However, the complex subject requires a differentiated overview of many factors—as described in the first part of this book. Only against the background of solid foundations can various applications in the sports environment be described and specific recommendations for a number of situations in sports practice be formulated in the second part of the book. However, it does not claim to represent all facets of the sleep-sport connection—some applications remain unconsidered, some aspects are neglected and much remains to be discovered.

This book is the result of a now twenty-year engagement with various subject areas at the interface between sleep medicine, sleep and dream research, and sports science within the framework of research projects, lectures, presentations, contributions in media, discussions, as well as consultations and finally through the supervision of all sorts of final theses and some doctorates. Therefore, my thanks go to

all those people who have discussed all these topics with me and thus enriched the book. I would also like to thank the employees of Springer-Verlag who were enthusiastic about the topic and professionally accompanied me during the creation of this book, especially Renate Eichhorn and Ulrike Niesel. I am infinitely grateful to Michael Schredl, my mentor and friend. Without his valuable support, this book would not exist. My greatest thanks go to my loved ones: Carmen, Jola and Jakob. You are the best!

Daniel Erlacher

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Basics

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Perspectives of Sports Science

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1

At a gymnastics training camp, young athletes practice a somersault dismount from the bar for the first time. A girl practices throwing a ball for a school championship. At the Olympic Summer Games, a medal hopeful in swimming faces an important qualifying race. The world of sports is colorful, diverse, and offers something that most people lack: experiences. "Sport" extends into many areas of life. It is part of culture. Part of society. It ranges from elite sports, from the Olympic Games, to grassroots, health, and school sports. It includes athletes who earn their living through daily training, boys and girls who manage a somersault for the first time, seniors who keep fit with Zumba or cross-country skiing. Sport is structured and organized—in clubs, leagues, school curricula, or in rulebooks. It includes classic millennia-old sports such as running or wrestling. And modern trend sports like parkour or CrossFit.

Accordingly, sports practice raises many questions: How often do the boys have to train until the somersault is perfect? What feedback should the teacher give the girl after a failed throw to optimize the learning process? How can the swimmer improve her mental strength to deliver a top performance in the race? The examples show that the questions and their answers strongly depend on the perspective: In this case, from a training science, movement science, and sport psychology perspective. They are among the sports science disciplines that maintain a natural and social science background and will be introduced in more detail in this chapter. One goal should be to especially reach those readers who have little experience in sports science and through these explanations gain a first insight into the academic world of sports.

The perspectives are not arbitrarily chosen, but concern the subject areas with interesting references to sleep and dream research: Is it worth taking a nap after the bar exercises to regenerate faster or even consolidate what has been newly learned? Before the school championship, the girl dreams at night of throwing balls and spears as far as possible. Will she achieve a new personal best because of the nightly "training"? The swimmer can't get a wink of sleep the night before the competition. Will the missed night's sleep affect her performance? In addition to training science, movement science, and sport psychology, sports medicine and sports biomechanics should also be considered. Here too, there are interesting points of connection. Thus, five of the eleven sections that are housed under the umbrella of the *German Association for Sports Science* are addressed, reflecting the diversity of natural, social, or humanities perspectives. For a detailed introduction to the academic discipline of sports science in research and teaching, refer to *Das Lehrbuch für das Sportstudium* (2013) edited by Arne Güllich and Michael Krüger [5].

The goal of sports science, from different natural, social, or humanities perspectives, is to describe, understand, and explain sports and people's participation in sports.

1.1 Training Science Perspective

Subject. Training science is the sub-discipline of sports science that deals with the content design and planning of training [8]. For example, it is about the question of how much weight one has to move with which exercises and how often in or-

der for the biceps to gain mass and thus become stronger. Closely linked to training is regeneration, because training planning always involves the design of recovery breaks—be it as breaks within a training session or as breaks between training sessions. When weight training stresses the muscles, catabolic processes, i.e., those affecting the breakdown metabolism, are set in motion. For example, energy is consumed, muscular structures are stressed (possibly damaged), causing the body to become exhausted. After training, the homeostasis, the balance, in the body must be restored. Therefore, anabolic processes, i.e., those affecting the build-up metabolism, dominate during regeneration. This is associated with replenishing energy stores and repairing injured muscle structures. Through repeated physical stress, the body adapts to these training stimuli with a more efficient energy supply and stronger muscles; which ultimately results in increased performance. When sports science talks about performance improvement, the improvement refers to the motor abilities: strength, endurance, speed, agility, and coordination. In regeneration, in addition to the temporal estimation, i.e., the question of how long it takes for various processes in the body to recover, there is also the question of whether this time can be shortened by .recovery interventions Typical offers include, for example, cold applications, autogenic training, massages, but also nutrition and sleep, to replenish energy reserves and restore muscle tissue.

Theoretical Anchoring. Training science initially emerged from the experiences of successful athletes. It is thus a field inherent to sports science. Through systematic observation, those training strategies that led to gold medals were identified. Performance optimization was long in the spotlight and the recipes of successful coaches were considered a sacred asset. However, since inductively gained knowledge also allows for false conclusions, the "master teachings" were increasingly put to the scientific test within the framework of sports medicine. Physiology plays the most important role for recovery. Since sports medicine has not been able to identify a clearly reliable biological marker in this area in recent decades, sport psychology is also becoming increasingly important. For example, creatine kinase as a physiological stress parameter can reflect changes through training, but it is not able to predict overtraining states in advance [9]. There, creating a recovery profile based on psychological indicators could be a better predictor of overtraining.

Research Methods. The quantitative recording of normative stress specifications such as volume, duration, frequency must be carried out in training science, as well as the systematic description of psychological and physiological stress parameters such as heart rate, muscular oxygen saturation or mental performance. The identification, description, development and standardization of suitable training parameters is the main focus. In performance diagnostics, motor sports tests and sports medical procedures are used. The project "Regeneration Management in Elite Sports" (REGman), funded by the Federal Institute of Sports Science in Germany, is a current project that reflects a good example of applied research in cooperation with training science, sports medicine and sport psychology [11]. It is about the development of different physiological and psychometric measuring instruments for quantifying and recording recovery and stress in sports.

References to Sleep and Dream Research. Competitive sports is the classic field of application of training science. Coaches are therefore just as interested in the optimal use and planning of stress norms as their proteges. Especially in regeneration through sleep, there should be a great interest of training science (► Chaps. 7, 8 and

9). In addition, knowledge about the optimal handling of jet lag (► Chap. 10) as well as knowledge about the effects of sleep deprivation (► Chap. 7) is of particular relevance.

1.2 Movement Science Perspective

Subject. Movement science is the sub-discipline of sports science that deals with the internal mechanisms of movement control and movement learning in the sports-active individual [7]. For example, it is about how the internal control processes of the support motor system act so that a gymnast can balance on a balance beam, or how the neuromuscular control changes so that over time a basketball player hits the basket more often. Motor skills refer to the efferent nerve pathways that run from the brain to the skeletal muscles and thus enable movements. The movements lead to actions that achieve an intended action goal, such as throwing a ball into the basket, in order to win a game. The focus on motor skills is somewhat unfortunate, as feedback on the success or failure of motor skills can only occur in the sensory system, i.e., in perception: ball in the basket-ball next to it. Perception refers to the afferent nerve pathways that run from all sensory cells in the body to the brain and thus form the motor-relevant information. To do justice to this interplay, one should actually speak of sensorimotor skills or perception-action coupling, if the interplay is to be located at a higher level. The goals of movement science relate to the control of actions and learning in a sports context. In sports practice, the findings from motor learning, for example, are transferred to methodical exercise series in order to enable rapid practice. For example, the basketball throw can be illustrated using the metaphor of a whip to convey the folding of the throwing hand. The arrangement of different movement executions, the giving of feedback or focusing of attention during movement execution can be addressed.

Theoretical Anchoring. Movement science draw on all disciplines that generally want to understand, explain or reproduce movements. After all, the control mechanisms to be explored in a basketball throw should not fundamentally differ if a child, a competitive athlete or a baker throws a ball. Within psychology, these are primarily cognitive scientific directions of motor skills and in medicine, neurology, which deals with movement disorders. But also computer science and engineering, which tries to teach robots to throw, has a keen interest in the topic. In current theories on motor skills, internal models are primarily discussed, which relate the motor commands to the sensory consequences. Usually, an inverse model and a forward model are assumed. The inverse model calculates the efferences that are necessary under given situational conditions to generate a movement with which the intended effect is achieved. The forward model calculates the effects that would occur under given situational conditions with certain efferent signals. Actual action results can thus be compared with the simulated effects and linked with the associated motor commands.

Research Methods. The research methods are primarily anchored in the experiment. To understand basic motor mechanisms, relevant parameters are systematically changed in control and learning tasks, for example, the variation of the at-

Fig. 1.1 Insight into laboratory research under the most realistic conditions (with kind permission from Steven Lingenhag)

tention focus on the hand or the basket in the basketball free throw. Bridging the theory-practice gap, i.e., the examination of as many sports motor movements as possible, is a constant challenge. All too often, the laboratory experiments are too "artificial" to directly transfer the results to the world of sports. Not least for this reason, virtual realities are increasingly being created in the laboratory in order to enable an investigation as close to sports as possible (Fig. 1.1).

References to Sleep and Dream Research. Movement science have ventured a first tentative exchange with sleep research in the context of memory consolidation, for example in studies in which the subsequent sleep was measured in the laboratory after learning sports movements (e.g., trampoline jumping) (► Chap. 11). Otherwise, points of contact with sleep and dream research in sports motor skills are rather sporadic. The explanations about the interplay of sensorimotor skills and sleep should arouse particular interest (► Chap. 13). In addition, the findings on motor learning in lucid dreaming should be of great interest. Are the learning effects there like mental training through a "mental" movement without actual execution. The explanatory approaches behind this should also concern motor learning theory (► Chap. 15).

1.3 Sport Psychology Perspective

Subject. Sport psychology is the sub-discipline of sports science that deals with the psychological components of sports participation [3]. Sport psychology is a broad field and covers various topics. For example, it addresses the question of why peo-

ple engage in sports at all and what motives play a role when a person prefers to climb mountains instead of playing handball. In addition to these theoretical questions, sport psychology also addresses applied questions and tries, for example, to promote the mental strength of athletes through sport psychological methods. Three areas of application of sports psychology should be highlighted here: sports psychological training methods, competition anxiety, and the psychological view on recovery and stress. Sport psychological training includes methods that relate to movement regulation or action regulation. In the context of the former methods, mental training is particularly well-known [4]. It has been shown several times that the repeated mental execution of, for example, a free throw in basketball improves the actual hit rate. The latter methods include psychoregulatory procedures such as autogenic training or progressive muscle relaxation. These interventions are intended to help athletes who, for example, experience fear in a competition situation, to regulate their negative emotions. The third field of application refers to the advantages of psychophysiological well-being scales already mentioned in training science, to monitor recovery and stress in the training cycle.

Theoretical Anchoring. The parent science of sport psychology is psychology, which is rooted in both basic research and clinical application. The classic fields of psychology such as perception, cognition, emotion, motivation, development or personality are transferred to sports topics. The aim of many theoretical approaches is to explain the description of human behavior in relation to person-situation. For example, action theory received great attention in sports psychology. Here, the human being is seen as an active, acting being that sets future-oriented goals and is able to plan and reflect on its actions. This model was used, for example, to explain the motivation of athletes in high-performance sports. Applied sport psychology tries to transfer theoretically gained knowledge to sports. A vivid example is the so-called training world champion, e.g., choking under pressure. That is an athlete who shows absolute top performances in training, but cannot call up his optimal performance in competition. If the causes lie in an emotional dysfunction, a helpful strategy can be offered to the athlete through behavioral therapeutic intervention.

Research Methods. The research methods of sport psychology have a broad spectrum and range from psychometrics, i.e., psychological diagnostics, through the experiment to the intervention study. There is extensive research on individualized intervention in athletes through mental training, both in basic research and in sports practical application [10]. Dealing with competition anxiety requires tailor-made psychometric scales such as the Competition Anxiety Inventory (WAI) [2]. For monitoring, for example, the risk of overtraining, the short scale for recording recovery and stress (KEB) in sports is very well suited [6]. These can also be applied in research in top-level sports during the training and competition process.

References to Sleep and Dream Research. Sleep and dream research still plays a subordinate role in sport psychology. However, the three application examples presented above should be evident for sport psychologists who are active in sports practice. Lucid dream training offers a cognitive training intervention that goes far beyond practicing techniques. Sleep management before, during and after competitions in sports (► Chap. 15) and the imparting of suitable strategies should be a fixed part of sports psychological care (► Chap. 9). Not only in relation to competition anxiety, but also in the psychological facets of stress and regeneration processes, sleep problems should be a serious signal. In the individualization of diag-

nostics, fatigue assessment and regeneration interventions, sleep is already firmly anchored (► Chap. 8). To what extent dream contents also offer additional information for diagnostics and intervention could be an exciting field of research (► Chap. 14).

1.4 Sports Medicine Perspective

Subject. Sports medicine is the sub-discipline of sports science that investigates the influence of athletic activity on the human body from both a clinical and performance physiological perspective [1]. The most common image is probably that of the sports doctor who runs onto the field when a superstar has been injured in a duel. This is obvious, as traumatic events such as bruises, sprains, and contusions most often affect the musculoskeletal system and need to be "fixed". Therefore, knowledge about the functional interplay of bones, joints, and muscles is fundamental. Physiology also plays an important role, for example, the provision of energy is a limiting factor in many performance sports areas. Energy supply is regulated by the intake of nutrients, the ventilation of respiratory gases, the circulation of blood, and the "consumers" in the muscles, to roughly name the most important cornerstones. Another core area concerns communication in the body, be it via nerve pathways to coordinate the interplay of muscles, or via hormones to regulate catabolic and anabolic processes throughout the body. The topics of sports-relevant connections could be continued indefinitely. However, another subject of sports medicine should be mentioned here: The systematic evaluation of sports therapeutic effects in health promotion, primary prevention, early treatment, and rehabilitation. It has been shown multiple times that sports therapy, for example, has a positive effect on the treatment of physical diseases (e.g., back pain) and psychiatric disorders (e.g., depression).

Theoretical Anchoring. Sports medicine is a cross-disciplinary field and draws on the knowledge of orthopedics, neurology, pulmonology, cardiology, endocrinology, and so on. The individual areas provide knowledge about the anatomical structure of the individual organ systems or their functional parts such as the musculoskeletal system, the nervous system, the lungs, the heart, or the hypothalamus. Physiology includes knowledge of organ functions at rest and under physical work such as the nerve-muscle interaction, ventilation, circulation, or hormonal regulation. The overview of all biological processes thus provides a basic understanding, for example, to understand performance changes through training. Pathophysiology, on the other hand, describes pathological changes in the human body, which on the one hand provide insights into the function of the affected organ systems and on the other hand are clinically treatable.

Research Methods. The research methods are anchored both in the basic area and in the clinical area. As a prime example of German-speaking sports medicine, reference is made to ergometry and performance diagnostics. The countless research works, for example, on lactate changes under stress, have led to invaluable knowledge both in research on metabolic metabolism and in competitive sports for determining performance status, training specifications, and adaptation effects. In the clinical context, randomized controlled intervention studies with sports inter-

vention on various diseases are mentioned. An example of this is the influence of High Intensity Training in cardiovascular rehabilitation.

References to Sleep and Dream Research. Sleep research should be of interest to sports physicians in all performance sports and therapeutic contexts. Sleep plays an important role in regeneration, so understanding sleep physiology, circadian rhythms, and sleep disorders should therefore represent basic sports medical knowledge (► Chaps. 2, 3 and 4). In preparation for major sporting events like the Olympic Games, sports medical care plays an important role. For optimal travel organization and acclimatization on site, knowledge about jet lag (► Chap. 10) as well as the effects of sleep deprivation (► Chap. 7) are of particular relevance. In the fields of application, the sports therapeutic effect on various sleep disorders, primarily insomnia, is exemplarily referred to (► Chap. 12).

1.5 Sports Biomechanics Perspective

Subject. Sports biomechanics is the sub-discipline of sports science that deals with the physical properties of the body and athletic movement [12]. While the sports physician is interested in healing a bone, the sports biomechanist analyzes, for example, at what force impact during the landing after a double somersault in gymnastics the bone is overloaded and possibly breaks. The interest can focus on individual tissue structures or on the physical description of the body in different sports situations. The division of topics into internal and external biomechanics is useful and necessary. The musculoskeletal system with the close coupling between skeleton and muscles is considered a mechanical system. The skeleton with all bones, bone connections, and joints forms the framework. The striated muscles, which are attached to almost the entire skeleton and span joints, form the "engine" that generates forces and changes joint angles. They receive impulses through the nervous system. The exact representation of the musculoskeletal system helps to describe the individual partial movements that have a specific function. With this functional analysis, it is possible to demonstrate movement structures in order to better understand, explain, and optimize movements. The goals of sports biomechanics range from optimizing sports motor movement techniques, to analyzing loads for injury prevention, but also optimizing sports equipment or sports clothing.

Theoretical Anchoring. The roots of sports biomechanics lie in physics and engineering. The laws of classical mechanics are fundamental and are divided into dynamics and kinematics. Joints are application examples for rotational movements, whose torques let a ball fly in an oblique throw. The biomechanical quantities show the entire range of physical parameters that make it possible to measure movements. The spatial-temporal changes are physically considered and thus provide the boundary conditions of the movement space and thus open up the possibility of optimization. In addition, complex features such as work and energy of a training unit can be calculated from the physical quantities. Moreover, the modeling and simulation of sports motor movements are becoming increasingly important.