CARINA SZKUDLAREK

# Artificial Intelligence in Strength Training

# Overview

# 01
# Introduction

The interdisciplinary nature of exercise science comes with many challenges, such as the multifaceted nature of data collection, the accuracy of knowledge generation, and the ease of use of equipment. As Artificial Intelligence nowadays is an indispensable part of our society, AI methods have also been used more and more in sports in recent years and seem to represent a viable solution that can be adapted to different sports.

With strength training as an example, this paper will give an introduction to what a future in AI-based strength training could potentially look like using the most recently studied technologies and an entirely new approach to training.

# 02
# Strength Training

Strength training is one of the most popular sports today at both, professional and amateur levels. The sport is commonly referred to as a special type of training in which lifting weights causes the overloading of a specific muscle or muscle group in order to trigger adaptive responses in the body, known as supercompensation. The positive effects of this form of training are general strengthening and improvement in physical condition, fitness, and performance. In addition to professional athletes, recreational and hobby athletes can therefore also benefit from strength training.

## Personalized vs Precision-based Training

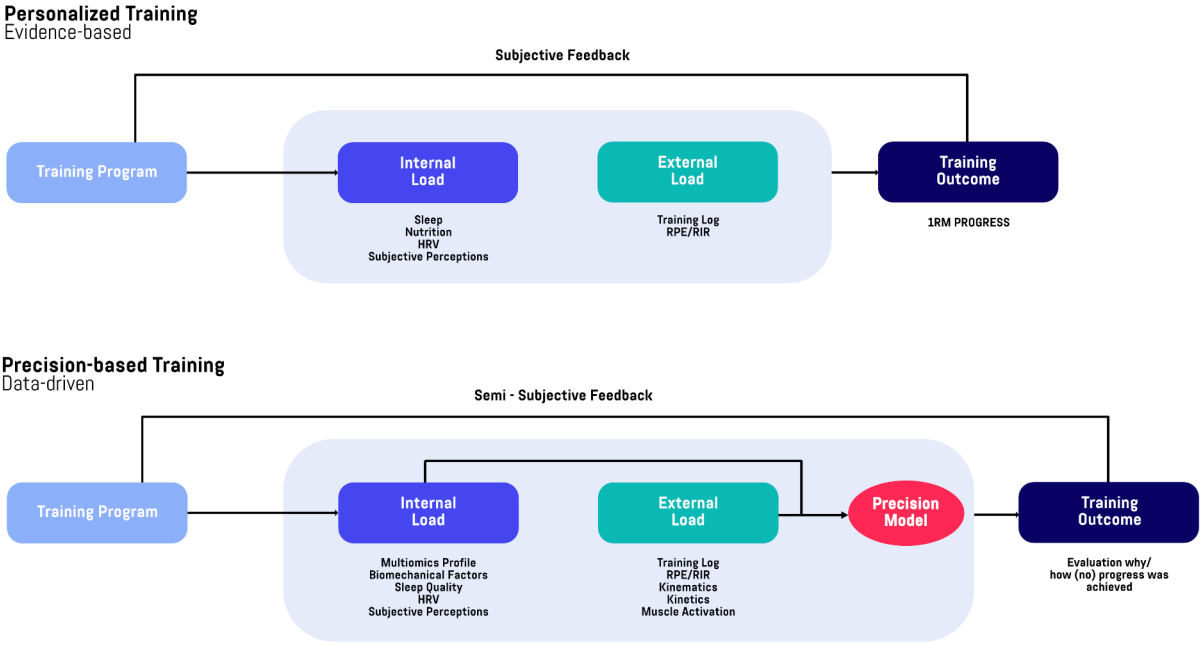
There are many definitions of strength training, however, the terms **Personalized Training** and **Precision-based Training** play a particularly important role in the context of AI. **Personalized Training** is based on feedback from a human trainer through evidence-based yet subjective decisions. Among other variables, the trainer is responsible for the design of the training but also for decisions on training interventions.

**Precision-based Training** means a data-driven analysis of training. In addition to the subjective feedback, athletes are monitored using sensor technology to analytically supervise training and execution in relation to human care and recovery [1].

Most of the methods used today to improve strength training performance still make little use of artificial intelligence technologies, although they could help improve training accuracy and precision. Coaches and athletes rely on their past experience to structure training methods and conduct analysis. However, these are usually imprecise, manual, and inconsistent assessments of the physical condition of the athletes in the training process and can easily lead to ineffective training. In addition, the existing processes lack the predictive analysis capability through mathematical modeling which could potentially provide a detailed analysis and evaluation of the individual athlete.

# Personalized Training

In personalized training approaches, the coach or the athlete himself makes the decisions about the training based on experience and existing protocols (as it has worked with many others). Factors here are above all the subjective feelings of the athletes through sleep and nutrition, additionally, there is the training stimulus and a result is measurable, for example, based on 1 RM (maximum strength of 1 repetition).




# Precision-based Training

AI can be used to evaluate other factors such as for example not only sleep but also sleep quality. Above all, in relation to training, with the help of AI also exercise execution can be precisely analyzed and specifically improved. Therefore with the use of a precision model, it is also possible to state more specifically why, but, if applicable, no progress was made in a cycle.

# 03
# The Need for AI in Strength Training

Free-weight training requires a tremendous amount of precision in technique. In order to enable a controlled and safe execution of exercises, many strength training machines are available to replace free-weight training for those who do not depend on it due to their profession such as powerlifters. Training on machines gives athletes a strict path of motion, but performing the exercises correctly still requires far more precision. For example, the graph (figure a) shows the measured parameters (cable force and weight transfer) on an incline press machine, highlighting inconsistent and erroneous characteristics with clearly discernible force fluctuations at the low point of a single rep. The visible oscillation in the cable force graph was caused by sudden unloading and subsequently increased loading, which is a common mistake, especially among beginners. Such anomalies as can be seen in figure a), make it easy to see that determinants such as force, displacement, speed, and duration are essential for analyzing the quality of the technique [Cf. 2].

Therefore, in order to be perfected, any style of lifting weights can profit from an additional evaluation that exceeds the capacity of most human potential.
If such features as mentioned above are known, an automatic evaluation of strength training exercises can be used with the help of sophisticated modeling methods. Beyond purely personalized training, the results can be integrated into an automated coaching system, which enables real-time analysis of movement quality, and feedback on information for improvement.

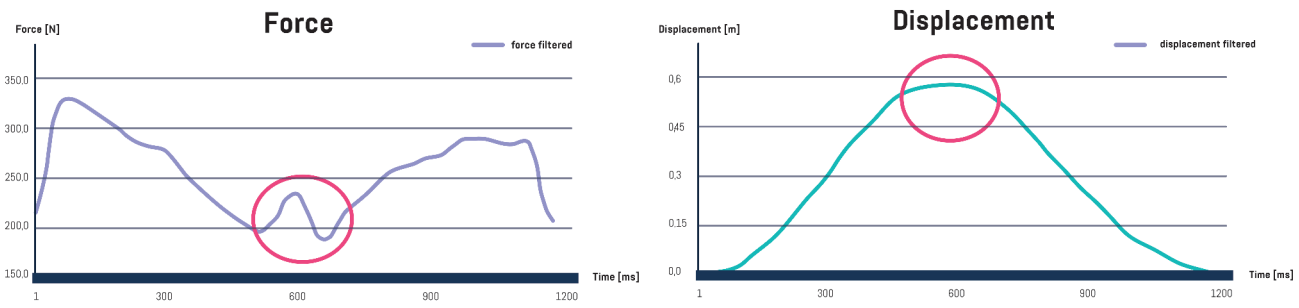



figure a)

# 04
# Technological Foundations

Many existing technologies are suitable for use in different areas of strength training and are also being investigated to simplify and perfect training for future athletes. In particular, with the increasing emergence of gadgets and devices such as Kinect or smartwatches, which have been repurposed for sports science, some inexpensive technologies could quickly be developed and a large amount of data can be easily collected in order to create models and analyses for performance monitoring in sports and training. Even smartphone-based kinematic data can be used to train precision force models. When integrated into a (mobile) coaching system [3], these techniques can support athletes with automated and instant assessment and feedback notifications in training.

As an example, a first success was gained through visualization and real-time feedback using motion capture. A 3D avatar was powered using a musculoskeletal model in which the human movement was simulated by muscle contraction dynamics. The avatar performed deadlifts with various weights to demonstrate realistic, weight-dependent execution. Models like such could be applied in real-time to quantify and visualize sufficient ankle and hip mobility before a heavy squat. As a result, the model could predict poor exercise readiness and accordingly suggest needed warm-up sets or an easier exercise.

Besides motion capture, there are several other methods studied currently, that could be particularly suited for capturing training data such as heart rate monitoring and the analysis of biomechanical markers.

## Motion Capture

Motion capture is particularly suitable for kinematic analyses of 3D data by quantifying the movement patterns of objects or people. The deep learning approach allows for modeling skeletal sequences which can then be displayed in 3D graphs where the nodes represent the joints of the skeleton. Additional characteristics can also be recorded and evaluated such as muscle stiffness, muscle activation, tendon stiffness, and range of motion (ROM) [Cf. 1].

## Heart Rate Variability

Heart rate monitoring is one of the first and currently most widely used methods in sports technology. The measurement is either optical via photoplethysmography (PPG, e.g. on the ring or on the smartwatch) or an Electrocardiogram (ECG). Typically used to monitor endurance sports, the method can also be used in strength training to assess or predict the athlete's overtraining and recovery or evaluate the impact of daily activities on recovery and performanc [Cf. 4].

## Biomechanical Tracking

Apart from electrical measurement methods, biochemical measurements from blood, urine, or sweat can also be used to monitor athletes for muscle damage and recovery status.

In particular, by analyzing the lactate and ammonia levels, metabolic exhaustion and neuromuscular fatigue can be detected at an early stage and thus minimized, or the recovery between individual training sets can be monitored and adjusted accordingly. However, this method is not yet suitable for everyday use [5,6].

# 05
# Implementations

Most advanced technologies required to feed a model for precision-based training, are still used very little to date. Yet, a majority of deep learning methods for strength training focus on recreational athletes and are available in the form of algorithms and models for exercise recognition, recording of a training diary, and monitoring adherence to the training plan [7]. An evaluation and correction of the exercise technique in real-time via motion capture and technique evaluation models or movement similarity models are also already partially integrated into common fitness apps [8].

Popular examples are **FitnessAI** [9], the **Biolayne Workout Builder** [10], or the Juggernaut Training Systems with their **JuggernautAI app** [11]. Aimed primarily at powerlifters, JuggernautAI uses athletes' feedback to create a program specific to their needs. The system automatically finds the right training volume, the optimal training frequency, and a personally adapted periodization of the training and exercises that are specifically aimed at individual weak points. Biolayne is suitable for every type of athlete, whether beginner or advanced. Using manual input of training data, the application calculates the necessary progression by adjusting sets, reps, pace, and even sets the weight for the next workout's working sets. Another well-known implementation, especially among powerlifters is FitnessAI. A video of the execution of one of the three main compound movements can be uploaded to the free-to-use website, which will then, based on motion capture technology, give a detailed examination and recommendation to the athlete [12].

For everyday use, AI technologies in precision strength training still lack a large number of data sets and in particular user experience. Still, these concepts find increasing amounts of popularity, not just in strength training. Professional and recreational athletes can most likely look forward to an upgrade to their training support in the near future.

# 06
# Literature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