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MOMENTS IN THE KNEE AND HIP DURING DESCENT AND ASCENT OF SQUATS

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The aim of this study was to compare the moments in the knee and hip during the acceleration phases, namely the descent and the ascent phase of squats. 20 subjects executed barbell squats with zero, 25 %, and 50 % body weight (BW) extra load. Based on motion capture and force data, an inverse dynamic calculation of the load condition of knee and hip was performed. The free chosen time for one repetition was less than 2 s. According to Newton's second law, it is expected that during the acceleration phases of the body and the extra load, the load conditions are higher. The experimental data shows only shows small differences in the range of a few percent during the acceleration and deceleration phases of the squat. Therefore, the main part of the loading during squatting is based on the body weight and the barbell and not due to the acceleration of the mass.

KEY WORDS: strength and conditioning, load condition, squat.

INTRODUCTION: Squat is besides dead lift and bench press one of the three classic exercises in strength training. Due to the high possible extra load during squatting and a high risk of wrong execution, this exercise can lead to injuries of the lower extremities of the back (Müller, 1999). Therefore, a correct execution of the squat exercise is important if not to compromise the positive effects of the training (Dunn et al., 1984, Cappozzo et al., 1985, Chandler et al., 1989, Fry et al., 2003). The squatting kinematics and kinetics are the base for recommendation of the proper execution of the exercise (Schoenfeld, 2010). According to the second law of Newton, during acceleration phase of a movement the force rises. This implies that the acceleration and deceleration phase of the squat influence the load conditions of the joints such as knee and hip. Therefore the aim of this work is to determine the differences of the joint moments in the knee and hip during acceleration and deceleration phase of squatting.

METHODS: Data Collection: Kinematics and kinetics of squat exercise was evaluated using a 12 camera 3D Vicon (Oxford, UK) system. The 20 subjects were all students of movement science with experiences in weight lifting. The average weight was 66 ± 12 kg, the age 24 ± 4 and the height 1.73 ± 0.08 m. They performed barbell squats with zero, 25 % bodyweight (BW) and 50 % BW extra loading. The barbell was placed on an upper position of the trapecius muscle. The stance was shoulder wide, the feed pointed slightly outwards. The subjects were advised to stabilize the lower back; the trajectory of the knee was not compromised. The subjects were free to choose the velocity of the executions. To measure the force for each foot, two Kistler force plates (Winterthur, CH) were used. The marker set consisted of 53 skin markers including 20 for the spine (Bachmann et al., 2008, List et al, 2011).
Data Analysis: The joint centers were functionally defined during specific motion tasks. The estimation of the joint rotations was based on a least-square fit of two point clouds and orthogonal anatomically defined joint coordinate systems. An inverse dynamic for the calculation of the moments, based on the position of the body and the ground reaction force was performed. To compare the load conditions of the different subjects, the moments were normalized to the body weight.

RESULTS: The time for one repetition is similar for all load conditions (Table 1). The normalized moments of the knee and hip are shown in the figure 1. The load pattern of the knee and in the hip is similar for all load conditions. In the knee, the difference between ascent and the descent phase increases with extra load. For knee angles smaller than ~80º, the moment is smaller for the ascent phase whereas the moment close to the deepest position is higher during ascent. Close to the point (about 5º away from the maximal knee angle) were the direction changes, the moment is 6 % (zero), 3 % (25 % BW) and 3 % (50 % BW) smaller for the descent phase. In the hip, the moment during ascent is slightly larger during the whole repetition. Compared to the knee, the differences between descent and ascent are smaller for the hip joint.

Table 1
Free chosen time for one squat repetition

Load condition	Time 1 repetition [s]
Zero	1.90 ± 0.76
25 % BW extra load	1.86 ± 0.73
50 % BW extra load	1.82 ± 0.85

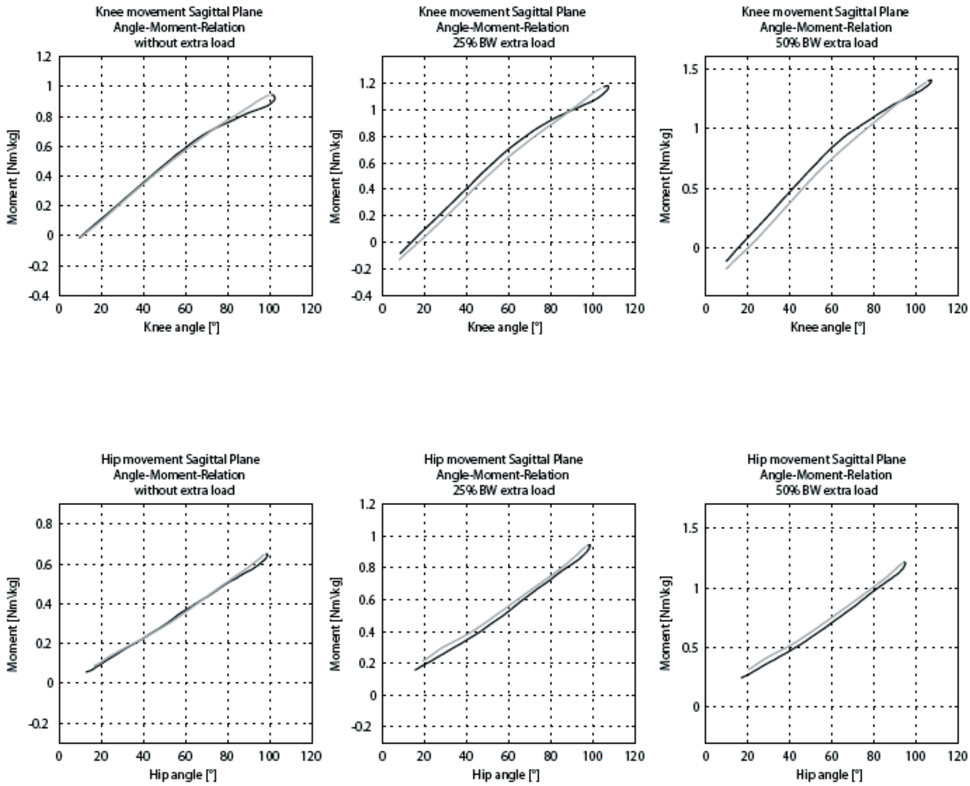

Figure 1: Top row: normalized moments of the knee without (left), 25 % BW extra load (middle) and 50 % extra load (right). Bottom row: normalized moments of the hip without (left), 25 % BW extra load (middle) and 50 % extra load (right). Black: descent, gray ascent.

DISCUSSION: Squatting is mainly an exercise for the quadriceps. Therefore a certain time interval is required to set a stimulus. Due to the high load to set this stimulus, squat is an exercise with a higher risk due to wrong execution or an overloading. Numerous guidelines concerning the execution of "the proper squat" exist. One of these rules is to avoid the change of the direction of the movement at a knee angle of 90°. The explanation is due to higher loading during the ascent phase compared to the descent phase of the squat.

This study showed that during squatting with free chosen speed, the load conditions of the knee and the hip are very similar during the acceleration and deceleration phases of the squat. An excessive additional loading due to the acceleration of the mass was not observed. Of course this is only valid for similar times of execution of one repetition. The common rule referred earlier to avoid the change of the direction of the squat at a certain angle of the knee to prevent extra load due to an extensive force might be re-evaluated.

The measured time for one repetition of the subjects might be representative for a non guided work out of individuals like in fitness centers or unsupervised workouts of team players. It represents a free chosen speed for most conditions during weight training. With a higher number of subjects it might be possible to make a shortening of the one repetition time with extra load visible. Nevertheless the result of this study would not be influenced by this.

Of course the results are only valid for similar or slower speed for the execution of one repetition. Especially during very high velocity weight training to enhance the speed and the acceleration of the athletes the outcome of such exercises might be different.

CONCLUSION: In this study the moments in the knee and in the hip were determined for the descent and the ascent phase of squatting. Furthermore the time for one execution was measured. No large differences were found due to the acceleration of the body and extra weight. Even at the deepest position of the squat were the directions of the movement change, the differences of the descent and ascent are in the range of a few percents. Of course these observations are only valid for executions times similar to the ones in this work.

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