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The Influence of Stress Factors on Joint Loading of Lower Extremities in Weightlifting

Einfluss von Belastungsgrößen auf die Gelenkbelastung der unteren Extremitäten im Gewichtheben

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Summary

› **Background:** It is unclear what influence stress factors have on joint loading in weightlifting. The aim of this study was to show how barbell weight and repetition affect the joint loading on the ankle, knee and hip in order to estimate the strain on the corresponding joint actuators.

› **Methods:** Six male weightlifters underwent a test with snatch pulls. For the analysis, the 85% and 110% weight stage (1RM Snatch=100%) and the first and fourth repetitions with 100% weight were used. The joint loading was measured using inverse dynamics. Statistical analysis was based on t-test and effect size.

› **Results:** An increased weight on the barbell only leads to higher NJM impulse in the ankle (p = 0.013; d=1.47; very likely positive) and hip (p=0.010; d=1.78; very likely positive). The NJM impulse for the knee was not affected by barbell weight. An increased number of repetitions at 100% weight only reduced the NJM work at the ankle (p=0.000; d=-4.61; most likely negative).

› **Discussion:** The stress on individual joints depends on barbell weight and repetition. It can be assumed that this altered stress influences how joint actuators are strained and what local training effect is obtained. Submaximal barbell weights with higher repetition rates are recommended for straining the knee joint actuators, while higher weights are necessary for exerting the ankle and hip joint actuators.

Zusammenfassung

› **Problemstellung:** Es ist unklar, welchen Einfluss Belastungsgrößen auf die Gelenkbelastung im Gewichtheben haben. Die Zielstellung der Arbeit bestand darin, den Einfluss von Hantellast und Wiederholung auf die Gelenkbelastung für Knöchel, Knie und Hüfte darzustellen, um eine Beanspruchung der jeweiligen Gelenkantriebe abzuschätzen.

› **Methoden:** Sechs männliche Gewichtheber führten in einem Trainingsexperiment die Trainingsübung Zug breit durch. Hierbei wurden Lasten von 85% und 110% (Bestwert Reißen=100%) sowie bei 100% die 1. Wiederholung und die 4. Wiederholung analysiert. Zur Bestimmung der Gelenkbelastung wurde die inverse Dynamik genutzt. Die statistische Analyse erfolgte über t-Test und Effektgröße.

› **Ergebnisse:** Eine Erhöhung der Hantellast führt nur im Knöchel (p=0.013; d=1.47; sehr wahrscheinlich positiv) und in der Hüfte (p=0.010; d=1.78; sehr wahrscheinlich positiv) zu einem höheren Gelenkimpuls. Der Gelenkimpuls im Knie bleibt konstant. Eine steigende Anzahl der Wiederholungen bei 100% Last hat dagegen nur auf die Gelenkarbeit im Knöchel einen Einfluss (p=0.000; d=-4.61; höchst wahrscheinlich negativ).

› **Diskussion:** Die Belastung der Gelenke in den unteren Extremitäten verändert sich innerhalb der TÜ Zug breit, wenn unterschiedliche Belastungsgrößen genutzt werden. Es ist anzunehmen, dass die Gelenkantriebe unterschiedlich beansprucht werden, wodurch differenzierte lokale Trainingseffekte entstehen. Für eine Beanspruchung des Kniegelenkantriebes empfehlen sich submaximale Lasten mit höheren Wiederholungszahlen, während die Gelenkantriebe für Knöchel und Hüfte vorrangig bei höhere Lasten beansprucht werden.

KEY WORDS:
Snatch Pull, Stress, Strain, Joint Moment

SCHLÜSSELWÖRTER:
Zug breit, Belastung, Beanspruchung, Gelenkmoment

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Introduction

In order to achieve a good lift, the athlete must exert force on the barbell, thus accelerating it to the necessary vertical velocity. If the goal is to lift heavier weights, the force on the barbell has to increase. Training that induces internal strain on the neuromuscular system based on external stress factors is necessary in order to achieve a neuromuscular response and as a result an increased force output (13, 22). With relation to this, the training focus is to strain the muscles that are responsible for the motion in major joints that are used in the desired task (2). Calculation of net joint moments (NJM) as joint loading (stress) is a feasible approach for estimating the strain on the corresponding joint actuators (all muscles or groups of muscles which can generate a movement ›

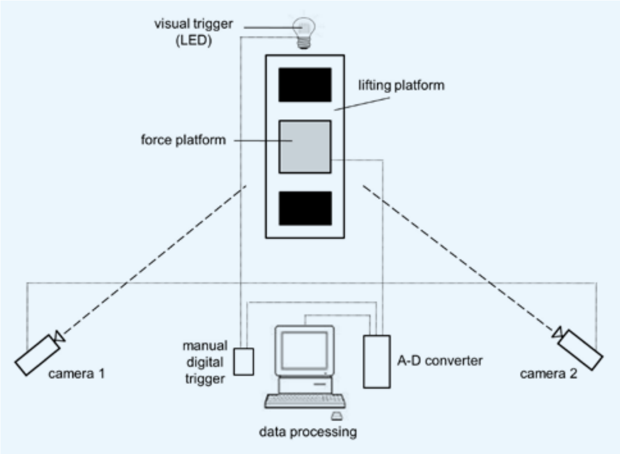

Figure 1
Experimental setup.

in a joint are denoted as joint actuators) (1). In an idealized instance, the measured NJM will reflect the muscular activity (strain) of the operating muscles / groups of muscles, by means of which a potential training effect can then be estimated (6, 21).

In the general training process of weightlifters it can be assumed that, when carrying out the same exercise, the varying stress factors will put an identical amount of strain on all the joint actuators involved. This assumption is not entirely correct. By using a NJM analysis in back squats Farris, Field, Lichtwark, Brown & Cresswell (11) and Flanagan & Salem (12) confirmed that an increased barbell weight only leads to higher NJM in the ankle and hip, whereas the NJM in the knee joint does not increase. Similar results have already been demonstrated in initial approaches for weightlifting exercises (snatch, clean) (3, 10, 17).

Problem and Aim

In weightlifting, the snatch pull exercise is used to develop specific speed-strength qualities for the acceleration phase of the snatch (competition exercise). It is unclear how stress factors affect NJM in the lower extremities in this exercise.

It is the aim of this study to examine how barbell weight and repetitions influence NJM in the ankle, knee and hip in snatch pull. The results will help to objectify the strain on these joint actuators and to estimate possible training effects.

Material and Method

Athletes and Test

Six out of ten male elite weightlifters from the German national junior squad participated in this study (age: 22.3±2.3 years; body weight: 83.5±11.4 kg; body height: 1.72±0.06 m). All athletes executed the snatch pull with one repetition at six weight stages from 85-110% of their personal best in snatch (=100%). In addition, they were required to lift the 100% weight with a set of four repetitions.

Data Recording and Analysis

The calculation of NJM for ankle, knee and hip were made using an inverse dynamic 2D-model (19, 24). For this model the following input parameters were used: 1) ground reaction forces (force plate PF1-2001, IAT, 500 Hz), 2) digitized body movement (two fixed and synchronized HDV-Camcorder, Canon XH-G1, 50 Hz; digitization via Mess3D, IAT) and 3) dynamic model properties (Fig. 1) (9, 24).

The snatch pull was split into 1st pull, transition, and 2nd pull based on alterations of the knee joint angle during the lift (14). For statistical analysis, only the 1st pull and the 2nd pull were used with the weight stages of 85% and 110%, as well as the 1st and the 4th repetition with 100%. According to Flanagan & Salem (12) we used NJM impulse (positive area under the NJM time-curve; dynamic load) and NJM work (positive area under the NJM-power time-curve; energetic load) as derivatives of NJM to estimate the strain on the corresponding joint actuators. All data are reported relative to body weight.

The statistical analyses were carried out using IBM SPSS 19 (IBM Corp., Armonk, NY, USA) and a Microsoft Excel spreadsheet from Hopkins (15). A t-test for paired samples was used for pairwise comparisons (α=5%).

To rate the practical significance, Cohen´s d effect size ±90% confidence limits (CL) were calculated (thresholds for d: 0.2-trivial; 0.6-small; 1.2-moderate; 2.0-large; 4.0-extremely large) (16). Moreover, the qualitative assessment of the percentage chance of a true practical effect (positive, trivial, negative) was based on the following scale: <0.5%-most unlikely; 0.5-5%-very unlikely; 5-25%-unlikely; 25-75%-possibly; 75-95%-likely; 95-99.5%-very likely; 99.5-100% most likely (16). In the case that the chances of both positive and negative effect were >5%, the effect was deemed unclear (16) (Tab. 1).

Results

Influence of Barbell Weight

An increased barbell weight leads to a significant alteration in NJM impulse for the ankle (p=0.013; d=1.47; very likely positive) and hip (p=0.010; d=1.78; very likely positive) in the 1st pull (Fig. 2). For the 2nd pull, only the NJM impulse in the hip changed in response to the increased barbell weight (p=0.015; d=1.12; very likely positive). In both pull phases, the NJM impulse for the knee is unchanged.

Concerning the NJM work, the increased barbell weight does not have a significant effect on the energetic load of the ankle or hip, neither in the 1st pull nor the 2nd pull (Fig. 3). In the 2nd pull, the increased barbell weight leads to a slight decrease in NJM work (p=0.053; d=-0.64; possibly negative) for the knee.

Influence of Repetition

In contrast to increased barbell weight, the number of repetitions does not have any influence on NJM impulse for the ankle and hip in the 1st pull. Instead, there is a significant change in NJM impulse in the 1st pull for the knee (p=0.046; d=0.71; possibly positive) (Fig. 2). There are no significant changes in NJM impulse in the 2nd pull for any joint.

Concerning the NJM work, there is a significant change in the 1st pull for the ankle (p=0.000; d=-4.61; most likely negative) (Fig. 3). The energetic load for the knee and hip is unchanged. In the 2nd pull there is again only a significant change for the ankle (p=0.001; d=-1.95; very likely negative), with no changes for the knee and hip.

Discussion

This study confirmed results from other investigations. In snatch pulls, an increased barbell weight leads to a higher NJM impulse (dynamic stress) in the ankle and hip, while the NJM impulse in the knee is unchanged. However, an increased barbell weight only has a minor influence on the energetic stress (NJM work) on the joints of the lower extremities. Based on these findings, it can also be assumed that the dynamic strain increased on the joint actuators of the ankle and the hip. In this case, the increased strain on the joint actuators of the ankle and the hip leads to a different training effect in comparison to the unchanged strain on the knee joint actuators.

The reason for the altered joint loading when increasing the barbell weight in snatch pull is due to modified movement coordination. With lighter weights, snatch pull is executed by means of a leg lift (synchronous extension of knee joint angle and hip joint angle and a parallel shift of the back), whilst with heavier weights the leg lift becomes a back lift (extension of knee joint angle precedes the extension of the hip joint angle with a forward-tilting back) (19). These kinds of changes in movement coordination are classified as a balance strategy (8, 18, 20, 23). It can be assumed that the back lift is a more advantageous lifting strategy for heavy weights due to the more favorable working conditions for the hip joint actuators (hamstrings) (7).

This study demonstrates for the first time that the number of repetitions have an influence on joint loading. With increasing repetitions, there is a decrease in NJM work at the ankle, while the NJM work at the knee and hip remains unchanged. ›

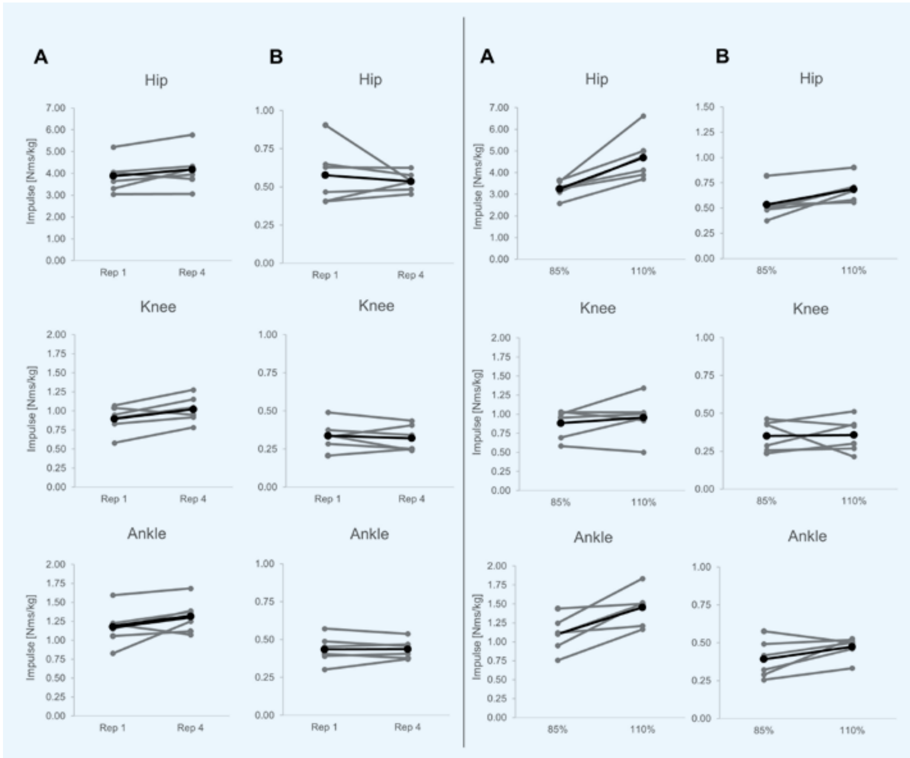

Figure 2

Influence of repetition (left) and barbell weight (right) on NJM impulse for the 1st pull (A) and 2nd pull (B) in snatch pull (gray=individual response, black=arithmetic mean)

Table 1

Results of statistical analyses for impulse and work in the 1st pull and the 2nd pull at the two weight stages (weight 85% and weight 110%) and two repetition stages (rep 1 and rep 4) in snatch pull (see method section for further explanations).

			1ST PULL				2ND PULL			
			DIFFERENCE AS COHEN´S D±90% CONFIDENCE LIMIT	QUANTITATIVE CHANCES (%) (POSITIVE/ TRIVIAL/ NEGATIVE)	QUALITATIVE INFERENCE	P-VALUE	DIFFERENCE AS COHEN´S D±90% CONFIDENCE LIMIT	QUANTITATIVE CHANCES (%) (POSITIVE/ TRIVIAL/ NEGATIVE)	QUALITATIVE INFERENCE	P-VALUE
Impulse	weight 85% vs 110%	ankle	1.47±0.78	96/4/0	very likely positive	0.013	0.80±0.84	67/32/1	possibly positive	0.116
		knee	0.31±0.65	21/77/2	likely trivial	0.373	0.06±0.94	15/74/11	unclear	0.911
		hip	1.78±0.89	98/2/0	very likely positive	0.010	1.12±0.62	95/5/0	very likely positive	0.015
	rep 1 vs rep 4	ankle	0.58±0.65	47/52/1	possibly trivial	0.135	0.01±0.42	2/96/2	very likely trivial	0.950
		knee	0.71±0.54	65/36/0	possibly positive	0.046	-0.18±0.59	2/87/11	likely trivial	0.569
		hip	0.36±0.41	14/86/0	likely trivial	0.140	-0.29±0.98	6/66/28	unclear	0.579
Work	weight 85% vs 110%	ankle	0.30±1.11	30/62/8	unclear	0.607	-0.05±0.73	7/84/9	unclear	0.902
		knee	-0.30±0.46	1/87/12	likely trivial	0.250	-0.64±0.51	0/44/56	possibly negative	0.053
		hip	0.65±0.74	55/44/1	possibly positive	0.140	0.33±1.01	31/63/6	unclear	0.536
	rep 1 vs rep 4	ankle	-4.61±1.04	0/0/100	most likely negative	0.000	-1.95±0.58	0/0/100	most likely negative	0.001
		knee	0.25±0.34	5/95/0	very likely trivial	0.194	-0.49±0.79	2/59/39	possibly trivial	0.265
		hip	0.00±0.47	2/95/3	very likely trivial	0.994	-0.48±0.68	1/62/37	possibly trivial	0.214

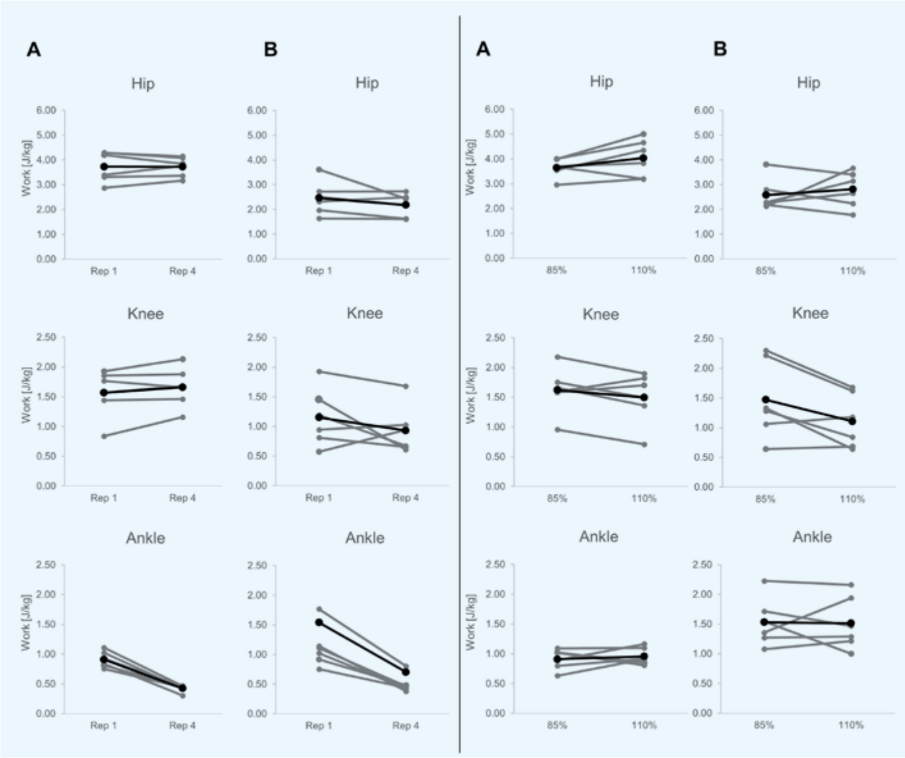

Figure 3

Influence of repetition (left) and barbell weight (right) on NJM work for the 1st pull (A) and 2nd pull (B) in snatch pull (gray=individual response, black=arithmetic mean).

It is assumed that by doing snatch pulls with medium weights and higher repetitions, the energetic strain for knee and hip joint actuators do not change, despite decreasing joint angle velocities (data not depicted). Therefore, when using more repetitions with lighter weights, it is expected that the joint actuators of the knee and hip adapt in a different way in comparison to the joint actuators of the ankle. A possible explanation for the decrease of ankle NJM work is a local fatigue effect (4).

The results show that different stress factors in strength training can modify how joint actuators are trained (dynamic vs. energetic load) and therefore determine which local training effect arises. This approach can provide a differentiated view when planning a training process in weightlifting or strength training in general. Not only the exercise itself is responsible for which joint actuators are being trained, but the composition of weights and repetitions can hypothetically shift the training effect at the joint level too. In a specific case of snatch pulls, the following scenario is conceivable: in order to strengthen the knee joint actuators (extension), submaximal weights (≤100% snatch) with more repetitions are sufficient. If the goal is to strengthen the ankle and hip joint actuators (extension), >100% weights are preferred. Depending on the requirements to improve the performance of the competition exercise – focus on a more powerful knee joint actuator for instance – the training process should not be focused on the general use of heavier and heavier weights for a specific exercise. Training should instead be focused on a weight-repetition design for a desired exercise targeted towards improving the weak link in the chain and thus improving competition performance.

Limitations of the study are the small sample size and the stress-strain-model that has not been validated until now. It is not entirely clear if NJM and their derivatives (impulse, work) are adequate measures from which to derive the strain of joint actuators in a lifting movement (5,23). In addition, the results of this study confirmed that changes in joint loading in response to stress factors are highly individual. Therefore it is advisable to carry out a single case analysis when making individual recommendations on how to train specific joint actuators.

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Conflict of Interest

The authors have no further conflict of interest.

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