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Open and closed chain loads in rehabilitation and training

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Introduction

The concept of "Open and Closed Kinetic Chain" was introduced by Steindler (1955). Since that time especially from the biomechanical point of view the stress produced by loads in the open and closed kinetic chain was measured and compared to discuss the question "Which load brings the greater advantage and is safer for the capsuloligamentous structures and joints ?" To answer this question the knee joint was the most investigated object.

The scientific discussion at first preferred the closed kinetic chain in the concepts of training and rehabilitation. But until today the question is not clearly answered in favour of open or closed chain. The advantage for the closed kinetic chain is justified, because alleged it is considered more functional in terms of the loads upon the joints and gets closer to the activities of daily life or is better at replicating functional movements.

Three main results (see below) seem to be clear, the discussion open and closed chain concerns (1) OKC and CKC are both implemented in daily activities, (2) the discussion open and closed chain concerns the species shear vs. compression forces (biomechanical aspect) and (3) the different sensorimotor control mechanisms of the movement (sensorimotor aspect).

The following facts are generally accepted

(1) The sensorimotor activities of daily life, profession and sports combine systematically loads of so-called OKC and CKC. So the basic movement of our life, the gait (Figure 1), connects a CKC motion during the stance phase and an OKC motion during the swing phase. Further simple examples of OKC movements in daily life and sport are take up an object or kicking a ball. On the other hand getting up of a chair and performing a pull-up are CKC motions. To classify trunk movements as open or closed chain motion is very difficult.

(2) From the biomechanical point of view during exercises there are typically two kinds of forces acting at the joint: shear and compression (Table 1; Lutz et al. 1993). Moving in an OKC there are preferential shear forces depending on the joint angle and the insertion of external force. The motion in a CKC indicates less shear but more compression forces. Compression forces are accompanied by enhanced friction, and thus joint stability is improved.

(3) From the neurophysiological (sensorimotor) point of view the OKC motion includes only one muscle or muscle group to move one joint (for example: extension or flexion the knee joint) and the CKC motion is a multi-joint movement with controlled co-contractions of synergistic and antagonistic muscles. The EMG recruitment pattern reveal that in relation to OKC the CKC exercise produces an increased sensorimotor co-contraction at the same angles (Figure 2; Lutz et al. 1993).

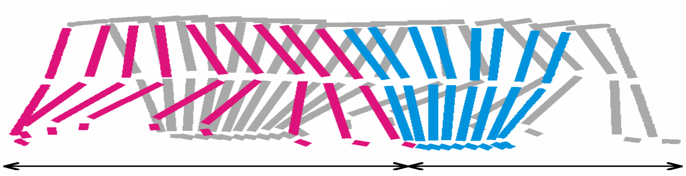

Figure 1: Human Gait Cycle

Exercise	Knee Flexion (Degrees)	Shear Force (N)	Compression Force (N)
Close kinetic chain	30 60 90	- 516 ± 392 - 538 ± 476 - 538 ± 165	3453 ± 131 3333 ± 143 2198 ± 805
Open kinetic chain extension	30 60 90	285 ± 120 160 ± 53 - 387 ± 67	1647 ± 694 2982 ± 783 3765 ± 716
Open kinetic chain flexion	30 60 90	- 939 ± 174 - 1526 ± 405 - 1780 ± 699	2154 ± 174 1024 ± 271 0 ± 0

Table 1: Tibiofemoral shear and compression forces (mean + s) during exercises in OKC and CKC in different degrees of knee flexion (positive value: anterior force; negative value: posterior force (Lutz et al 1993).

Specifications concerning muscle activity have to be made

There are different activation patterns in relation to the modus of load. For example the quadriceps muscle activity is greatest in CKC (squat, leg press) when the knee is near full flexion and in OKC (knee extension) when the knee is near full extension.

OKC produces more rectus femoris activity while CKC produces more muscle activity of the vasti (Escamilla et al. 1998).

Executing a knee extension motion in the open kinetic chain the EMG-activity of the antagonist (hamstrings) is low and additionally only measurable in the terminal range of motion (Baratta et al. 1988, Draganich et al. 1989). Similar EMG-activities can be seen during the swing phase of the gait.

Working in the closed kinetic chain the recruitment pattern is not always optimal for the strengthening of the muscle (Ninos et al. 1997).

Blackard et al. (1999) compared the mean integrated electromyographic values during biomechanically comparable closed kinetic chain (fixed external load) and open kinetic chain (moveable no load, and moveable external load) exercises. The results lead to the conclusion, that activities of similar biomechanical motions and mass of loading have comparable EMG values. Also the study suggests, that the external load is more important in describing human activity.

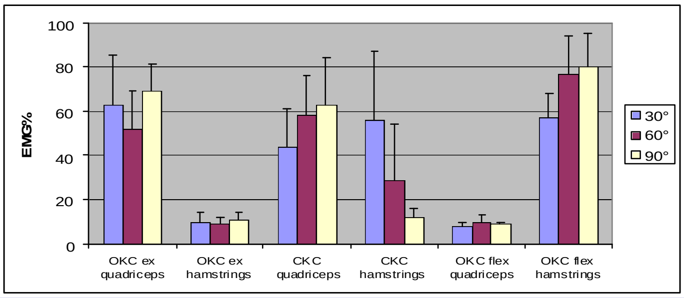

Figure 2: EMG (mean ± s) of quadriceps and hamstrings muscles during knee extension (OKC ex) and knee flexion (OKC flex) in an OKC and knee (flexion) extension exercise in a CKC (Lutz et al 1993).

Some questions are still open

(1) With which efforts the best results can be achieved for the aims: (a) strengthening a muscle of a chain (for example: quadriceps muscle); (b) improvement and "restoration" of static and dynamic stability (concentric, eccentric and stretch-shortening cycle), together with the best sensorimotor control and coordination by sensorimotor training ?

(2) Up to which loads the joint structures respond with adaptations or maladaptations to the training or therapeutic program using OKC or CKC efforts or both ?

(3) In which time period on one hand the range of motion and on the other hand following injury (for example) the restored ACL needs and copes which intensities of a minimum level of loading to induce the remodelling?

(4) How do we have to describe the structure of the daily life movements ? Where there are loads in the open and / or closed chain and how are both combined ?

(5) Which load related effects are existent in the joints and especially in the connective tissues of the joints ?

(6) Which therapeutic loads in relation to the clinical status and the time period of the rehabilitation process are possible and necessary for remodelling the injured structures ?

(7) How the musculature is used (recruited) during loads in the open and closed chain ?

(8) Which functional possibilities we have to sustain and to improve by training to realize the professional and daily life activities ?

Conclusion

The training and rehabilitation programs must combine loads in the open and closed kinetic chain because both are an integral part of the sensorimotor behaviour in daily life, profession and sport. Both are needed for the systematic realization or remodelling of adaptations in the muscle and joint tissues. From the clinical point of view the actual load capacity decides which forces, shear or compression, are possible to reach positive tissue reactions or to protect the injured structures.

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