Xco-Trainer: empty talk or real effect?

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Summary

This study examined the difference in muscle activity between training with an Xco-Trainer and a solid weight. It was decided for this study to concentrate on the muscle activity of m. biceps brachii and m. triceps brachii during a flexion-extension movement of the elbow. This movement is conducted at three speeds, namely 40, 60 and 80 movements per minute. Using an arm support and video camera, the starting position and the movement were standardised. Ten study subjects participated in the study. Each study subject carried out the movement at the three different speeds. The first three sessions were done with the Xco-Trainer. Then the same three sessions were done with the solid weight. Between each session there was a two-minute interval of complete rest.
Results: The results of this study showed a significant difference in the muscle activity. Training with the Xco-Trainer required more muscle activity at each speed than the solid weight. The greatest difference is about 39% for m. triceps and about 20% for m. biceps (in favour of the Xco-Trainer). The total percentage difference in muscle activity of both muscles together can reach about 56% at the same speed (in favour of the Xco-Trainer). Of the three speeds tested, the greatest difference in muscle activity occurred at 40 repetitions per minute.

Keywords: Xco-Trainer, Reactive impact, surface-EMG

1. Introduction

In physiotherapy it is becoming increasingly important that patients participate more actively in their course of treatment. Along with passive treatment methods, training under the supervision of a physiotherapist is done more frequently, with the aim to improve the patient's stability, coordination, muscle strength and endurance. To achieve these aims, various aids are available, like pulleys, Bosu balls and dumbbells. These aids are being continuously developed to improve their functionality. There are also innovations in the range of training aids. One of them is the Xco-Trainer. The Xco-Trainer is a tube filled with a granular substance that can move freely inside it[1]. This creates an impact at the conclusion of the movement, as the loose mass arrives at the end of the tube. This impact is called the 'reactive impact'. According to its inventor, this produces an additional mechanical load on the muscle fibres and the connective tissue covering[1,2]. Various studies have also revealed that the Xco-Trainer has a positive effect on raising the heart rate, oxygen consumption and energy use[3,4]. In this study we examined the difference in muscle activity when training with an Xco-Trainer compared with a solid weight, using surface-EMG.

2. Problem formulation

Prior to starting the study, the following two research questions were formulated:

1. Is there a difference in the amount of muscle activity of m. biceps brachii and m. triceps brachii during a flexion-extension movement of the elbow when using the Xco-Trainer in comparison with the solid weight?

2. Does the frequency of the flexion-extension movement of the elbow affect the reactive impact and muscle activity?

3. Hypotheses

Before formulating the hypotheses, a literature review was conducted for studies using the Xco-Trainer. Research had been done into the 'reactive impact' by the Movement Technology Expertise Centre (ECBT) in The Hague. By measuring the moments of a moving 'arm' with an Xco-Trainer or solid weight at the end, the reactive impact was demonstrated. In Fig. 1 the results are depicted of a moving arm with the original Xco-Trainer and a solid weight. Three peaks are evident, namely[5]:

- The first peak indicates the size of the moment of arrival at the point of reversal;
- The second peak indicates the vibration of the arm;
- The third peak indicates the size of the moment of impact after reversal, the reactive impact.

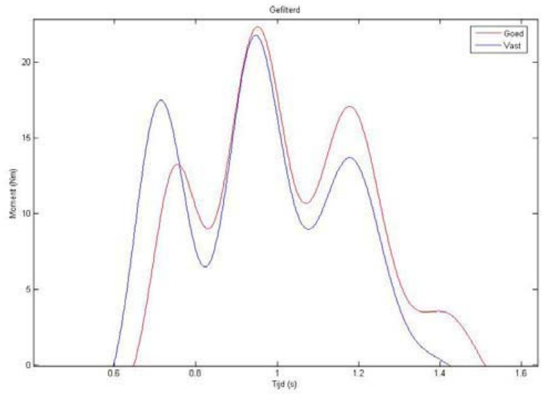


Figure 1*: Graph of the 'reactive impact'. The red line is the Xco-Trainer, and the blue line the solid weight. The reactive impact is visible as the third peak.[5]*

It can be concluded from this that the reactive impact produces a greater moment than the solid weight. This leads to the first hypothesis:

1a. The group expects that during the flexion-extension movement of the elbow with the Xco-Trainer, a peak load will occur at the instant of reactive impact.

As moment is the product of force times the arm (see formula 1), the force will be greater for a greater moment and the same arm.

*Formula 1: M=F*a*

With dynamic contractions, the height of the EMG signal (muscle activity) is not directly proportional to the external load.[6,7] Thus, the reactive impact, measured as a higher external load, does not lead to a directly proportional increase in the EMG signal.

1b. The group expects that with the reactive impact, more muscle activity will be evident during the concentric contraction in comparison with a solid weight.

As seen in Fig. 1, the reactive impact takes place after reversal of the movement. This means that there must be a greater load in concentric terms. It is thus postulated that an increase in the EMG signal is evident when there is a higher external load, the reactive impact. As this is not directly proportional, no estimate of the exact size of the external load can be made.

2. The group expects that the difference in muscle activity between the Xco-Trainer and the solid weight is the greatest at a frequency of 60 repetitions per minute.

According to its inventor, Jan Hermans, the reactive impact has the greatest effect at this frequency. At a higher frequency, the Xco-Trainer would act as a solid weight. At a lower frequency, the reactive impact would create too small an additional load.[2]

4. Methods

During the movement, the motion of the Xco-Trainer must be kept as horizontal as possible to ensure the validity of the study. This makes the influence of gravity equivalent at both 'ends' of the travel path. It was decided to bring the Xco-Trainer at the ends of the travel path to an angle of 45° from the horizontal. To achieve this, the humerus must be fixed by an arm support with the shoulder held in an anteflexion position of 120°. From this position a flexion-extension movement is made repeatedly in a path from 75° flexion to 165° extension in the sagittal plane. During the movement the Xco-Trainer is held in the middle, as indicated by a tape.

To examine the difference in muscle activity and reactive impact at different speeds of movement, three frequencies were selected. The frequencies were indicated by a metronome. The movement protocol was conducted at the frequencies of 80, 120 and 160 beats per minute (bpm). Each beat of the metronome indicated the end of a flexion or extension movement. Thus, 80, 120 and 160 bpm stand for 40, 60 and 80 repetitions per minute, respectively.

Ten study subjects participated in this study. They met the following inclusion criteria:

- Aged between 18 and 30 years old;
- Free of symptoms in the upper extremity;

- Minimal mobility range: Shoulder: 130°/0°/-; Elbow: 170°/0°/0°;
- Right-handed people.

5. Study design

The surface-EMG is used to measure the muscle activity during the flexion/extension movement of the elbow. The electrodes were placed on m. biceps brachii and m. triceps brachii, between the motor point and the distal end of the muscle belly. The medial epicondyle of the humerus was used as the reference point. Calibration of the EMG was done with a relaxed, extended arm in the support.[6,7] In the extension position, the first marker was placed with the EMG. Concurrently, the marker was placed by the Minimod, to ensure that the measurement was done synchronously. During the movement, markers were positioned with the EMG at the instant that a full movement path was complete.

The Minimod was used to measure the angular velocity during the movement. The angular velocity leads to the achieved angular acceleration by differentiating this signal, which ultimately indicates the reactive impact. As described in the hypothesis, the reactive impact is namely expressed in moment. As the moment is the product of the mass moment of inertia and the angular acceleration (see formula 2), it can be assumed that given the same mass moment of inertia, the angular acceleration is a measure of the moment.

*Formula 2: M=I*a*

The Minimod is fixed to the distal part and the dorsal side of the underarm just proximal to the wrist. Fig. 2 shows the apparatus design with the measuring equipment used.

The digital video camera was connected to a computer which produced a direct image. This provided the study subject with visual feedback about the performance of the movement.

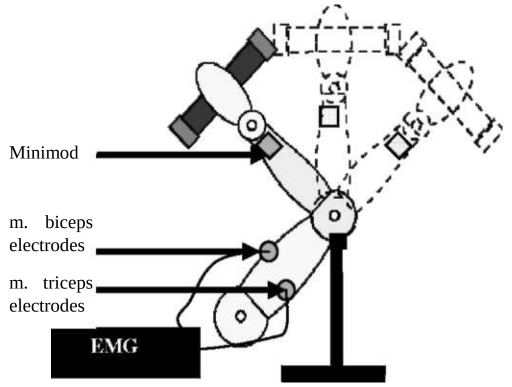


Figure 2: *Schematic reproduction of the apparatus design.*

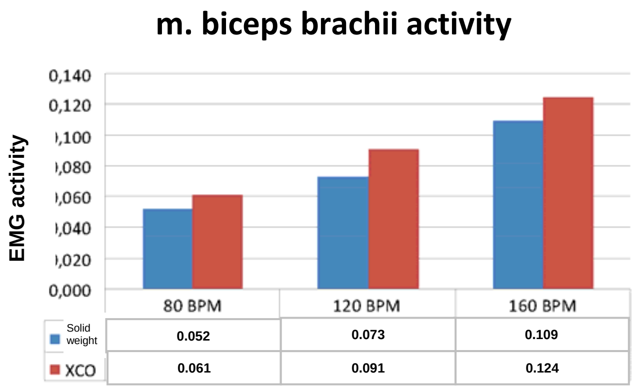
6. Data analysis

The study subjects served as their own controls. The total measurement took 40 seconds. The measurement results were derived from the middle 20 seconds as the study subject was still finding the correct rhythm and movements in the first 10 seconds. The last 10 seconds were also not included in the measurement results, as they are often influenced by the study subject's fatigue. For the remaining course, the mean muscle activity was calculated. The mean muscle activity with the solid weight was compared with the mean muscle activity with the Xco-Trainer. This was done for all 10 study subjects and at all three speeds for both m. triceps and m. biceps brachii activity.

The minimod signal was differentiated to obtain the angular acceleration and display the reactive impact.

7. Results

For all ten study subjects, the total percentage difference in muscle activity of m. biceps and m. triceps brachii between the solid weight and the Xco-Trainer at the three speeds is presented in a graph.



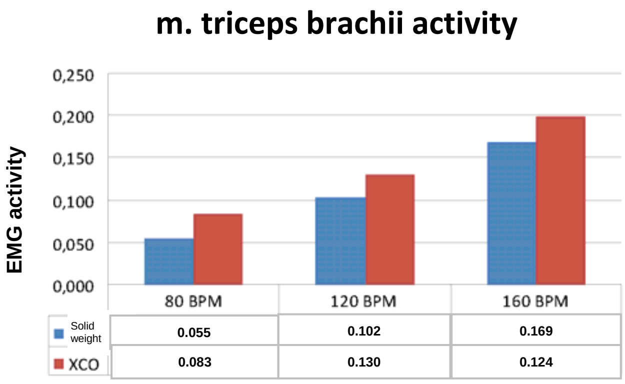
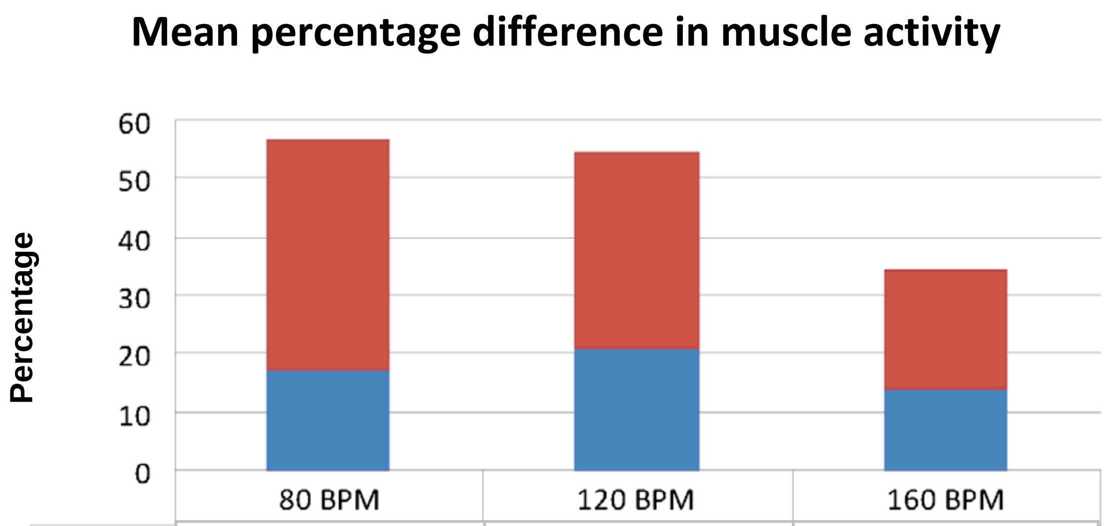


Figure 3. *The mean muscle activity of m. biceps and m. triceps brachii for the 10 study subjects at three different speeds.*

It is evident that at all three speeds, the mean muscle activity of both m. biceps brachii and m. triceps brachii is higher with the Xco-Trainer than with the solid weight. In Fig. 4 this total difference in muscle activity is expressed in percentage.



	80 BPM	120 BPM	160 BPM
Triceps	39.22	33.89	20.34
Biceps	17.30	20.91	14.09

Figure 4: *The mean percentage difference in muscle activity measured for m. biceps and m. triceps brachii at three different speeds over a course of 20 seconds.*

The mean percentage difference in muscle activity of all ten study subjects for m. biceps brachii at 40, 60 and 80 repetitions per minute amounted to 17%, 21% and 14%, respectively. The mean percentage difference in muscle activity of all ten study subjects for m. triceps brachii at 40, 60 and 80 repetitions per minute amounted to 39%, 34%, and 20%, respectively. Fig. 4 shows that the difference in muscle activity between the Xco-Trainer and the solid weight is the greatest at a speed of 80 bpm. In Fig. 5 the reactive impact is evident as the second peak of the Xco-Trainer signal. This second peak is missing from the solid weight graph.

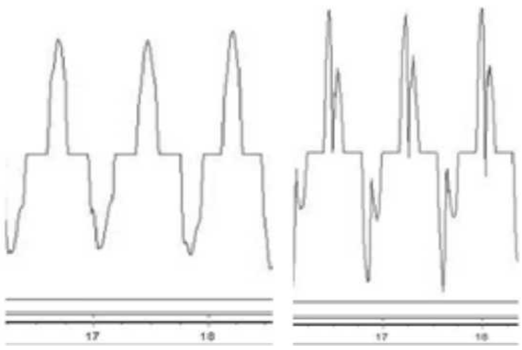


Figure 5: *The differentiated minimod signal at a speed of 120 bpm. Left: solid weight. Right: Xco-Trainer.*

8. Conclusions

From the minimod data it seems that there is a difference in the angular accelerations with the use of the Xco-Trainer compared with the solid weight. As assumed in the hypothesis, there is a second peak evident. This peak reflects an additional moment. The additional moment is also called the reactive impact.

The results reveal that there is a significant difference in the mean muscle activity with the use of the Xco-Trainer compared with the solid weight. This difference applies to both m. biceps brachii and m. triceps brachii at all three speeds. The total muscle activity measured increases with increasing speed with both the Xco-Trainer and the solid weight. The difference in muscle activity decreases, however, with increasing speed. The greatest difference between the Xco-Trainer and the solid weight occurs at 40 repetitions per minute. The total difference in muscle activity of m. biceps brachii and m. triceps brachii together amounts then to 56%.

9. Discussion

The first hypothesis assumes that during the flexion-extension movement of the elbow with the Xco-Trainer, a peak load arises at the time of the reactive impact. This could not be proven because the EMG apparatus was not precise enough. The reactive impact occurs in less than one-tenth of a second. The EMG apparatus had a minimum frequency measurement limit of 10 Hz (0.1 second). It was ultimately decided to use the muscle activity over a timeframe of 20 seconds.
This made it impossible to measure the muscle activity precisely during the reactive impact. No conclusion could be drawn about whether a peak load occurs or not. Nor could a conclusion be drawn about the type of contraction occurring during the reactive impact.

To ensure that the movement was done correctly by the study subject, the video camera was used to reproduce a direct image on the computer. This image was subject to a delay, however, making it a poor reference after all. It was decided to use just auditory feedback.

Following the correct rhythm appeared to be difficult, as the sound of the granular substance masked the beat of the metronome. Thus, sometimes corrections had to be made with auditory feedback during the measurement, which could have affected the measurement results.

Finally, large differences were evident between the results of individual study subjects. This could be due to variations in the movement conducted. Despite receiving the same explanation, it was interpreted differently by the different study subjects. It also appeared to be difficult for some study subjects to keep the wrist in the correct position. As a result, the Xco-Trainer did not always achieve 45° from the horizontal at the ends of the movement.

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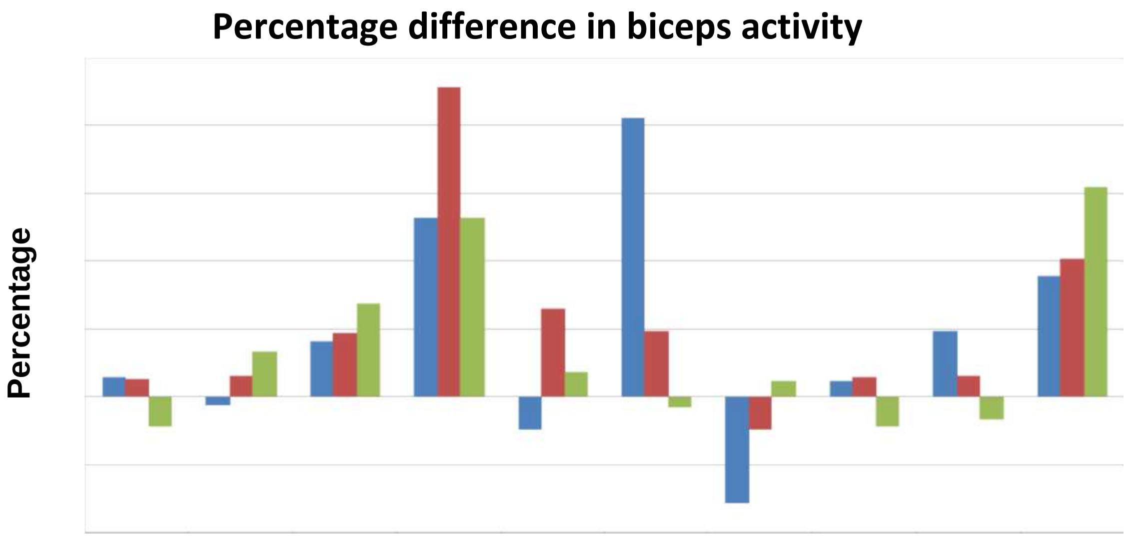
Appendices

This appendix contains the measurement data of the EMG presented as a table with a graph. As described in the data analysis section, we took the mean muscle activity over a timeframe of 20 seconds. This is expressed in the table. The percentage difference between these values is presented in the graph.

Table 1: Mean EMG measurement results of m. biceps brachii at the three different speeds.

M. biceps brachii activity	80 bpm		120 bpm		160 bpm	
	Solid weight	XCO	Solid weight	XCO	Solid weight	XCO
Study subject 1	*0.043*	*0.046*	*0.064*	*0.067*	*0.115*	*0.105*
Study subject 2	*0.074*	*0.072*	*0.093*	*0.099*	*0.121*	*0.137*
Study subject 3	*0.037*	*0.042*	*0.053*	*0.063*	*0.074*	*0.095*
Study subject 4	*0.085*	*0.130*	*0.102*	*0.195*	*0.169*	*0.258*
Study subject 5	*0.100*	*0.091*	*0.119*	*0.150*	*0.157*	*0.168*
Study subject 6	*0.045*	*0.083*	*0.079*	*0.094*	*0.129*	*0.125*
Study subject 7	*0.030*	*0.021*	*0.055*	*0.050*	*0.070*	*0.073*
Study subject 8	*0.043*	*0.045*	*0.064*	*0.068*	*0.115*	*0.105*
Study subject 9	*0.032*	*0.039*	*0.048*	*0.050*	*0.079*	*0.074*
Study subject 10	*0.032*	*0.044*	*0.050*	*0.070*	*0.065*	*0.105*

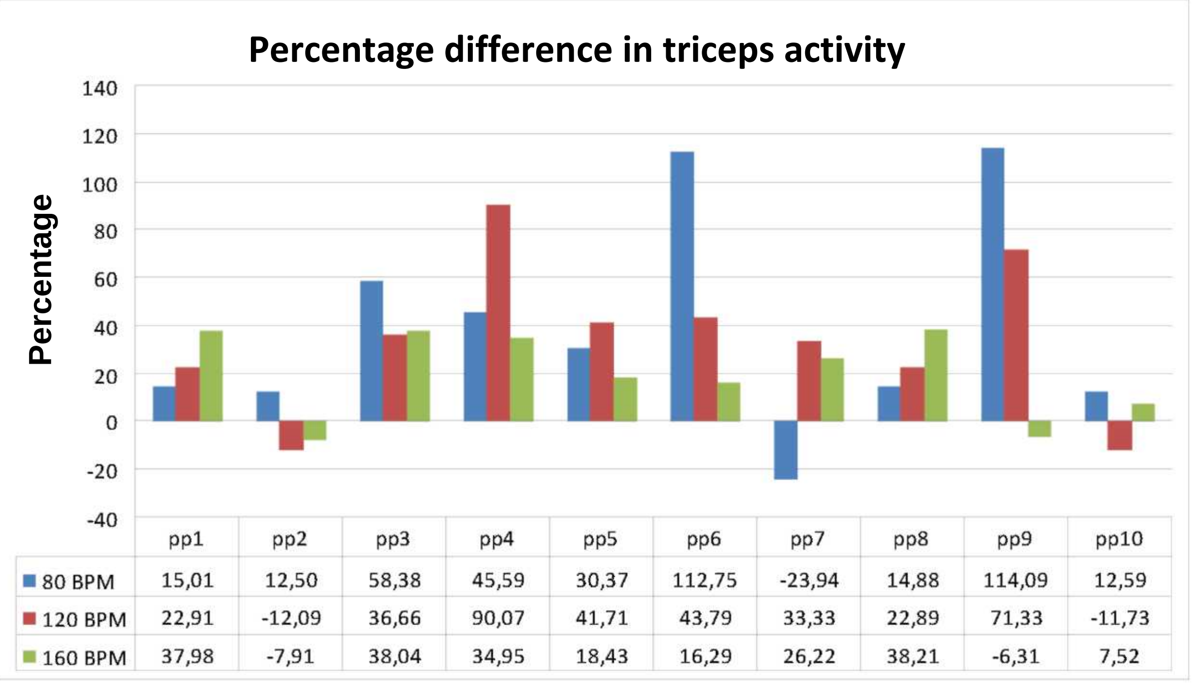


	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10
80 bpm	5.43	-2.56	16.23	52.69	-9.37	82.26	-31.25	4.56	19.56	35.39
■ 120 bpm	5.09	5.97	18.98	91.17	26.18	19.18	-9.45	5.54	6.05	40.43
■ 160 bpm	-8.39	13.26	27.31	52.86	7.05	-3.02	4.49	-8.35	-6.45	62.15

Graph 1: Percentage difference in m. biceps brachii activity of ten study subjects (SS) at the three different speeds.

Table 2: Mean EMG measurement results of m. triceps brachii at the three different speeds.

M. triceps brachii activity	80 bpm		120 bpm		160 bpm	
	Solid weight	**XCO**	**Solid weight**	**XCO**	**Solid weight**	**XCO**
Study subject 1	*0.033*	*0.038*	*0.058*	*0.071*	*0.100*	*0.137*
Study subject 2	*0.046*	*0.052*	*0.090*	*0.079*	*0.116*	*0.107*
Study subject 3	*0.057*	*0.090*	*0.096*	*0.131*	*0.175*	*0.241*
Study subject 4	*0.074*	*0.108*	*0.099*	*0.189*	*0.163*	*0.220*
Study subject 5	*0.086*	*0.113*	*0.131*	*0.186*	*0.206*	*0.244*
Study subject 6	*0.063*	*0.135*	*0.123*	*0.177*	*0.241*	*0.280*
Study subject 7	*0.065*	*0.049*	*0.101*	*0.153*	*0.170*	*0.215*
Study subject 8	*0.033*	*0.038*	*0.058*	*0.071*	*0.100*	*0.138*
Study subject 9	*0.041*	*0.087*	*0.112*	*0.191*	*0.279*	*0.262*
Study subject 10	*0.048*	*0.054*	*0.079*	*0.070*	*0.139*	*0.149*



Graph 2: Percentage difference in m. biceps brachii activity of ten study subjects at the three different speeds.