# Calculation forces from bar movement on parallel bars in gymnastics

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Modern artistic gymnastics apparatus have elastic properties, which the gymnast should use. It is important to know how a gymnast can give energy to the apparatus, especially to the bar(s) and how the stored energy can be used by the gymnast. The parallel bars were not included in such questions in the research yet. A static calibration at different positions of one bar was utilized as a precondition for the calculation of the forces during gymnastics exercises. Using synchronized 2D-video-analysis of the bar movement and the gymnasts performance (2 cameras) we calculate the forces based on our calibration. Examples of force-time-curves from parallel bars dismounts from German national gymnastics team will be shown. Using force-time-characteristics for supporting motor learning is a difficult task for the future.

**KEY WORDS:** artistic gymnastics, parallel bars, bar movement, forces, dismounts

**INTRODUCTION:** Optimal technique in artistic gymnastics depends not only on the movement of the gymnasts body parts. It is also important to use the elastics properties of the gymnastics apparatus. Differences of hard and elastic surfaces (Krug, Minow & Jassmann, 2001), use of elastic springboards (Sano, Ikegami, Nunome, Apriantono & Sakurai, 2004, 2007), coordination of gymnasts and bar movement on high bar (Krug, Knoll, Wagner & Bronst, 1998) and the energy exchange between the body of the gymnast and the high bar (Arampatzis & Brüggemann, 1999) are major fields of research in gymnastics. The properties of modern parallel bar are fundamental for the elements performed by the gymnasts at international competition. Elements on parallel bar like giant swing (Prassas, Ostarello & Inouye 2004) or basket or rather felge to handstand (Veličković, Kolar & Petković, 2006; Hiley, Wangler & Predescu, 2009) have been investigated. However, there is not enough information about the elastic properties and the coordination of the gymnasts' movements on parallel bars. Bringing the gymnast's movement and bar movement into resonance will lead to better performance.

The aim of our preliminary study is to take the first step to build a measuring system which could be used for supporting gymnast's technique training. A dynamometric measuring system on parallel bars was first invented by Schmidt (1973). The instrumented parallel bars were used to measure vertical and horizontal forces. Current parallel bars have more elastic bars than in the 1970s.

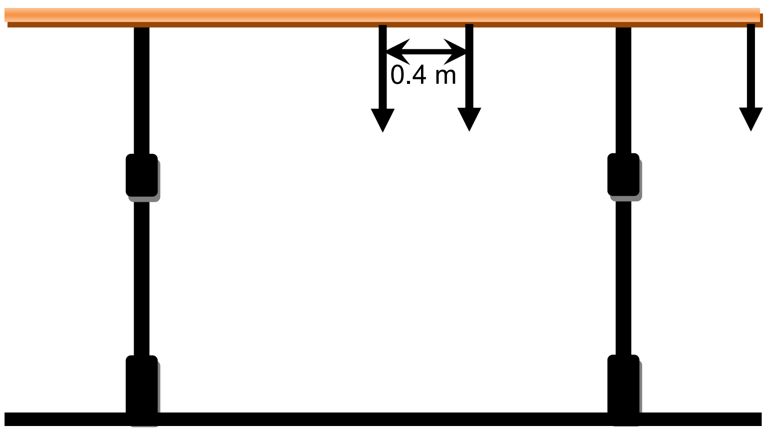


**Figure 1: Location of the Calibration points on the bar.**

**METHODS:** To calculate forces from the bars movement a calibration of one bar was necessary. For this investigation we used a static calibration with defined weights. The parallel bars were located at the national training camp for the German national gymnastics team. The apparatus was from the official supplier of the Olympic Games in Athens 2004 and Beijing 2008, Janssen-Fritsen Gymnastics from Helmond, Netherlands. We fixed weights on three positions on one bar (Figure 1 and 2). The first position was the centre of the bar, second 40 cm out of the centre and third the end of the bar. Often gymnasts start their routines at the end of the bar, that's why this position is also important. We used weights of 50 kg, 100 kg and 150 kg. We took pictures from every weight level and measured the bar movement in vertical direction. Based on this data a formula was created to calculate the vertical forces from the bar position. An example formula for the centre position is shown (Formula 1).

$$\text{Force [N]} = -0{,}2847b^2 + 35{,}784b \qquad \text{(where b is bar position)} \qquad (1)$$

We also carried out the calibration for a bar from another European manufacturer. The bar was made by Spieth, Esslingen, Germany (supplier of the World Championships in Stuttgart 2007) and it has slightly different properties.

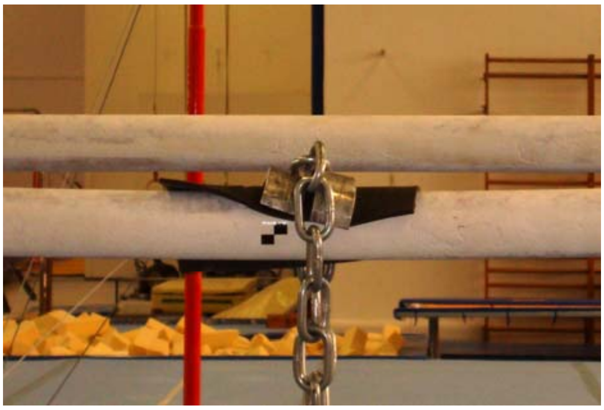

**Figure 2: Fixation of the weights on the bar.**

**Figure 3: Gymnast near the marked bar.**

Applying this formula to bar movements during exercises of the gymnasts (Figure 3) the estimated forces on the bar were calculated. We used two synchronized cameras (Basler) with 640 x 480 pixel resolution and 100 Frames per second. Video recording was done by the software Templo (Contemplas). The cameras were set up for a 2D-Analysis. The first camera recorded the movement of the gymnast and the second camera was focused on the bar movement using only a small part of the first camera view. For data analysis we digitized manually the movement of the bar and the gymnast with the Software MESS2DDV from Drenk (IAT Leipzig).
Different elements with high value in the gymnastics rules, the Code of points (Fédération Internationale de Gymnastique, 2009) were analyzed (Giant swing (Value C), basket or rather felge to handstand (Value D), roll backward with somersault backward tucked to upper arm hang (Dimitrenko, Value E), dismounts like double somersaults backward pike (Value D)). Force-time-curves of absolute and relative vertical forces were calculated. For overall forces it is necessary to double the forces. This is only valid under the precondition of symmetric element (symmetric forces on both bars) as named before. Other elements with single support on only one bar or no simultaneous release of the hands (elements: Diamidov, swing forward with ½ turn to handstand) were not included into our analysis.

**RESULTS:** The example in figure 4 shows the force-time-velocity-curves for the dismount of two different gymnasts. The starting position for both gymnasts was the handstand. Both relieve the bars, but gymnast 1 (blue) pull the bar up. Gymnast 2 (red) has a higher and earlier force maximum.

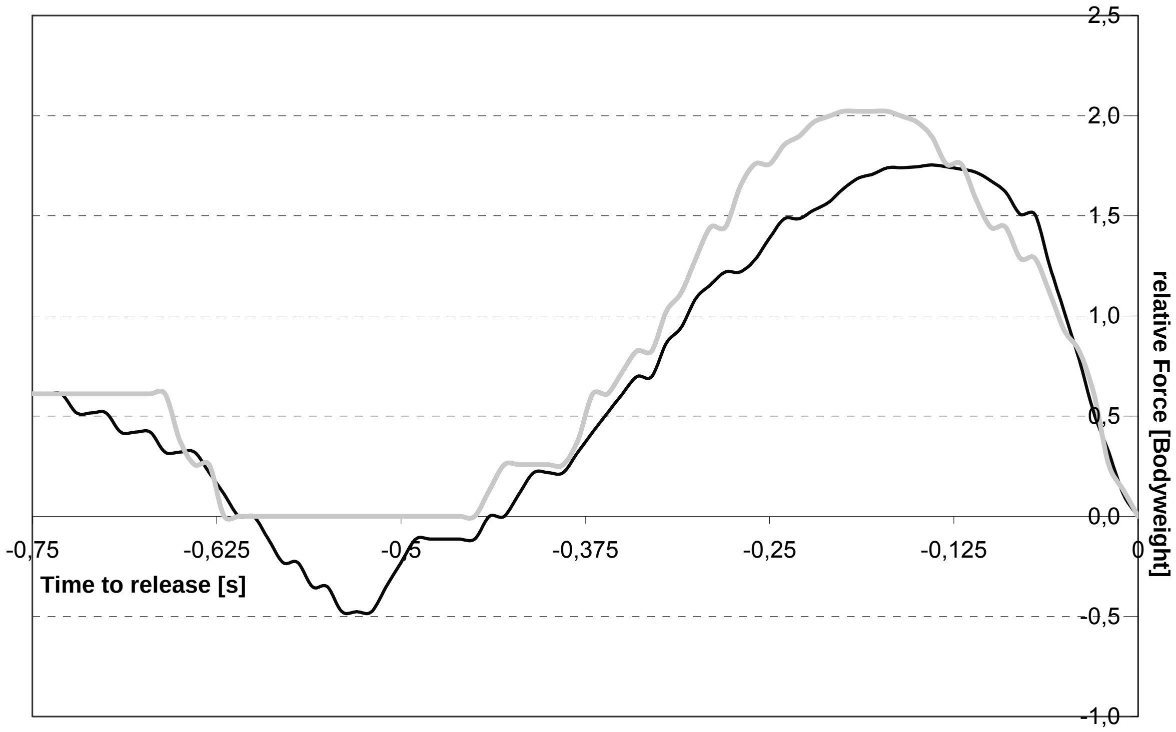


**Figure 4: Force-time-curve from two gymnasts doing a double somersault backwards dismount from parallel bars (vertical force on one bar).**

**DISCUSSION:** The study shows the possibility of calculation forces from bar movement. This first step is only usable for vertical forces. Differences between two gymnasts for the dismount are visible. These may be characteristics for a better technique. Gymnast 2 (grey) is a more successful gymnast. For a better understanding of the force-time-characteristics detailed analyses of the gymnasts' movement are necessary.

**CONCLUSION:** Manual digitizing of the bar movement for calculation forces can only be the first step. Further developments are necessary to get quick information about the bar movement and the forces. Automatically detecting of a marker on the bar and direct measuring of bar flexion e.g. with strain gauges are challenges for the future. However there is one problem: Forces of the gymnast result not only in flexion of the bar, also the other parts of a modern parallel bar take forces in. Using force-time-characteristics for supporting motor learning of gymnasts is a difficult task for the future. Typical force-time-curves from gymnasts of different performance level will be used for detecting movement errors. More data about the elastic properties of the bars are necessary for a better understanding of energy exchange between the gymnast and the parallel bars.

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