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Research article

Correct, Fake and Absent Pre-Information Does Not Affect the Occurrence and Magnitude of the Bilateral Force Deficit

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Abstract

The present study examined whether different pre-information conditions could lead to a volitional modulation of the occurrence and magnitude of the bilateral force deficit (BFD) during isometric leg press. Twenty trained male adults (age: 24.5 ± 1.7 years; weight: 77.5 ± 7.1 kg; height: 1.81 ± 0.05 m) were examined on three days within a week. Isometric leg press was performed on a negatively inclined leg press slide. Each participant completed three maximal isometric strength test sessions with different pre-information conditions given in a graphical chart: no pre-information (NPI; first day), false pre-information (FPI; bilateral force > sum of unilateral forces; second or third day) and correct pre-information (CPI; bilateral force < sum of unilateral forces; second or third day) during bilateral, unilateral-left and unilateral-right leg-press. The sum of left- and right-sided force values were calculated for bilateral ($F_{BL} = F_{BL\_left} + F_{BL\_right}$) and unilateral ($F_{UL} = F_{UL\_left} + F_{UL\_right}$) analyses. Force data for NPI revealed: Mean (SD): F_{UL_NPI} = 3023 N (435) vs. F_{BL_NPI} = 2812 (453); FPI showed F_{UL_FPI} = 3013 N (459) vs. F_{BL_FPI} = 2843 (446) and the CPI revealed F_{UL_CPI} = 3035 (425) vs. F_{BL_CPI} = 2844 (385). The three (no, false, correct) x 2 (F_{UL}, F_{BL}) rANOVA revealed a high significant main effect of Force (F = 61.82, p < 0.001). No significant main effect of the factor Condition and no significant interaction between Force x Condition was observed. The BFD does not rely on the trueness of the given pre-information (no, false, correct). Cognition-based volitional influences on the BFD on supra-spinal level seem negligible.

Key words: Bilateral force deficit, strength training, lower extremities, unilateral strength.

Introduction

In a pioneering study Henry and Smith (1961) found that the total force generated in a maximal bilateral hand grip test was significantly reduced compared to the sum of the right and left maximal unilateral hand grip strength. In the last decades force differences between one- and two limb exercises have been reported for various maximal strength tasks (isometric elbow flexion and extension, isometric knee extension, leg press and vertical jumps) (Oda and Moritani, 1995; Koh et al.,1993; Schantz et al., 1989). This phenomenon is usually called bilateral force deficit (BFD) and defined as a reduction in the amount of force produced from bilateral movements of homonymous limbs compared to the sum of forces produced by the left and right limbs when acting alone (Sale, 1992). Depending on the exercise mode (static vs. dynamic, isolated vs. complex tasks), the extent of the BFD was reported to range between 7 to 25 % (Owings and Grabiner, 1998, Jakobi and Chilibeck, 2001). These varying magnitudes of the BFD are considered to be caused by methodological restrictions (randomization and testing procedures), sport-specific stroke patterns (bilateral or unilateral limb movements), training-induced changes of muscle length, muscle activation, muscle fiber types, the type of exercises (multi joint vs. single joint, dynamic vs. static) and motivational prerequisites (Howard and Enoka, 1991).

However, the underlying central as well as peripheral neuromuscular mechanisms leading to lower bilateral strength are still not fully understood. It has been proven that decreased activation of fast motor units (Koh et al., 1993; Secher et al., 1978), reciprocal inhibitions on spinal level and inter-hemisphere inhibition on supra-spinal level (Ohtsuki, 1994; Taniguchi, 1998) may account for the BFD. Interestingly, also volitional modulations have been hypothesized (Koh et al., 1993; Secher et al., 1988).

In this regard, Jakobi and Chilibeck (2001) as well as Secher et al. (Secher et al., 1988) discussed whether a priori achieved information on the theoretical basis of the BFD may influence its occurrence and magnitude. From a physiological point of view, expectations of the force output according to previously achieved information were reported to influence maximal voluntary force and force development (Sahaly et al., 2001). In this regard, sensorimotor feed-forwards related to the expected force-output have been frequently discussed (Blakemore et al., 1998; Diedrichsen et al., 2007). Thus, internal force prediction during strength tasks might rely on the provided visual information, afferent information and expectations. In summary, motor commands appear to be interfered with knowledge and imagery (Lorenzo et al., 2003).

As a consequence, the present study was conducted to examine a sample of non-specifically trained young adults in order to differentiate whether an absent, false and correct pre-information prior to force testing potentially affects the occurrence and magnitude of the BFD during a combined maximal isometric hip- and leg-extension (leg press). Based on the assumption that visual afferent information may provoke expectations of force outputs, we hypothesized that an inverse (false) instruction of the theoretical basis of the BFD might lower the extent of the BFD compared to experiments performed with correct pre-information. From a practical relevance

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view-point, a verification of this assumption would emphasize (a) the importance of correct instructions due to expected force-outputs (b) to consider the manipulative impact of acute instruction-based placebo/nocebo effects during strength testings.

Methods

Subjects

Twenty trained young male adults (age: 24.5 ± 1.7 years; weight: 77.5 ± 7.1 kg; height: 1.81 ± 0.05 m, practiced sports disciplines: soccer, n=8; boxing, n=3; powerlifting, volleyball, basketball, swimming, tennis, gymnastics, track and field, each with n = 1; all-round sport, n = 2) were initially examined on a leg press slide (Figure 1) (Ertelt and Blickhan, 2009). None of the participants reported any medication intake and internal as well as orthopedic health impairments (hypertension, knee or hip injuries) that could affect maximal isometric strength testing. The local ethical committee of the University of Jena previously approved this strength measuring approach. No additional approval was needed concerning the present study. Furthermore, the study complied with the declaration of Helsinki and all participants signed an informed written consent prior to the start of the study.

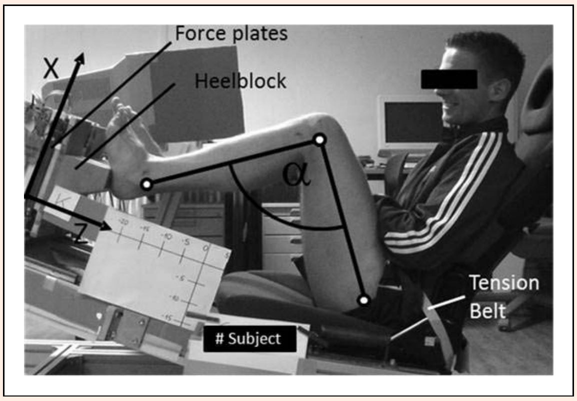

Figure 1. Exemplary positioning of the participants on the negatively inclined isometric leg-press slide.

Study design

The present study was conducted as a semi-randomized controlled cross-over trial. All participants were examined on three days within one week on Monday, Wednesday and Friday. Testing was intra-individually performed at the same time of day. On the first testing day, no theoretical pre-information (NPI) concerning the theory of the BFD was provided prior to maximal isometric strength testing. On the second day, a standardized false (incorrect: "you are able to produce higher force values during bilateral leg press, compared to the sum of left- and right-sided unilaterally generated forces") pre-information (FPI) or the correct pre-information (CPI) was randomly given ("The sum of left- and right-sided unilaterally generated forces is higher than force values during bilateral leg press"). This information was provided with a graphical chart. To ensure that the participants understood the given information, they were asked to repeat and explain the introduced pre-information condition. For each testing day, the order of the tested strength tasks (unilateral left, unilateral right, bilateral) were inter-individually assigned in a random order. The intra-individual testing order was not changed within the three testing days.

Data acquisition and analysis

Randomized isometric strength testing was unilaterally (UL_{left}, UL_{right}) and bilaterally (BL) performed on each of the three testing days. Three maximal isometric attempts per testing condition (UL_{left}, UL_{right}, and BL) were captured. Thus, a total amount of nine maximal strength testing attempts was performed on each testing day. The strength testing device (Ertelt and Blickhan, 2009) consisted of two separately placed strain gauge-basing force plates (DMS Type: J2A-06-31k-350, Tetra, Ilmenau, Germany) in order to measure horizontal and vertical (x- and z- components) ground reaction forces up to 30 kN with a sample rate of 500Hz. Data acquisition and operation was controlled by µ-MUSICS" (Integrated Measurements & Control (IMC), Madison, USA). The x- and z-components were calculated using a software tool (Famos, Integrated Measurements & Control (IMC), Madison, USA) for the total resulting force for each leg. Participants were fixed at the seat using a tension belt and the knee angle was fixed at 90°. The angle was verified by an analogous goniometer. In order to minimize an unintended contribution of the calf muscles, particularly the double-joint gastrocnemius muscle, all participants were requested to press with the plantar heel (Wagner et al. 2006, Siebert et al. 2007) (Figure 1). After a short general warm-up (hopping, stepping and squats within three minutes) and preparing for strength testing, the participants were instructed to press as strong as possible against the heel-block for a total of 3 seconds. Thereby, the participants were constantly encouraged by the vocal instruction "press, press, press" within the strength testing periods.

The consecutively highest force values of the three attempts for each pre-information condition were included into further analysis. The force plate raw data (ascii-files) were processed with Matlab (R14, MathWorksTM, Natrick, MA, USA). Thereby, the sum of left and right sides force values was calculated for bilateral ($F_{BL} = F_{BL\_left} + F_{BL\_right}$) and unilateral ($F_{UL} = F_{UL\_left} + F_{UL\_right}$) analyses. Force data were provided in Newton. According to the specified equation, the Bilateral Force Index (BIF) was calculated according to Howard and Enoka (1991). Thereby, a negative BIF-value is indicating a BFD.

$$BIF = \left(100 \cdot \frac{F_{BL}}{F_{UL}}\right) - 100$$

Statistical analysis

Data were normally distributed (Kolmogorov-Smirnov test) and, thus, presented as means and standard deviations. Then, a 2 Force (BL, UL_{sum}) x 3 Condition (NPI, FPI, CPI) repeated measures analyses of variance (rANOVA) was calculated. Due to the cross-over design both factors were included into analysis as dependent variables. Tukey HSD post hoc tests were conducted in case of a condition effect or Force by Condition interaction.

Results

A BFD was observed in more than 90% of all force measures (Figure 2). The mean BIF-value for NPI was -7.2 ± 4.1%, compared to -5.6 ± 4.8% for FPI and -6.2 ± 3.9 for CPI.

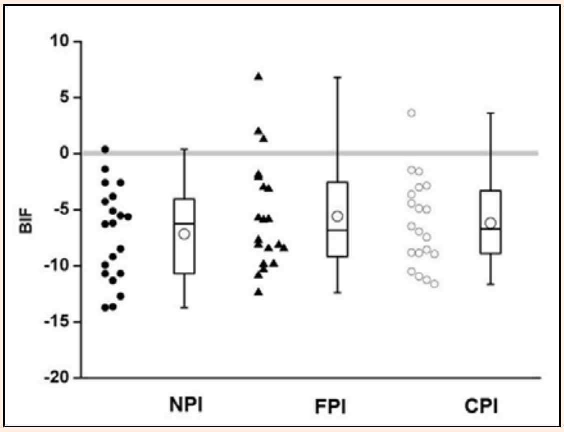

Figure 2. Bilateral Force Indexes (BIF) are presented for no pre-information condition (NPI), false pre-information condition (FPI) and correct pre-information. Data are indicated as single data plots, means (circles), medians (horizontal line within the box), 25.-75. percentiles (box) and 5.-95.-percentiles (whiskers) for each pre-information condition.

The rANOVA revealed a significant main effect of the factor Force (F = 61.82, p < 0.001). No significant main effect of the factor Condition and no significant interaction between Force and Condition were observed. According to univariate ANOVA computings, means and standard deviations for the bi- and unilateral force values for all pre-information conditions were as follows:

no pre- information (NPI): summed unilateral = 3023 ± 435 N vs. bilateral = 2812 ± 453 N (F = 65.8, p < 0.001)

false pre-information (FPI): summed unilateral = 3013 ± 459 N vs. bilateral = 2843±446 N (F = 24.7, p < 0.001)

correct pre-information (CPI): summed unilateral = 3035 ± 425 N vs. bilateral = 2844 ± 385 N (F = 49.2, p < 0.001).

Discussion

The present study demonstrated for the first time that occurrence and magnitude of the BFD both seem to not depend on the given pre-information condition (no, false, correct) achieved prior to strength testing during a standardized combined hip- and leg extension (leg press) in young adults. Leg-press exercises are considered to reliably reproduce a BFD during isometric exercises (Jakobi and Chilibeck, 2001; Taniguchi, 1998). Independent of pre-information conditions, the mean BIF values ranged between -5.6 and -7.2%. Thus, the magnitude of the BIF is in line with previous findings using isometric leg-press approaches (for review see Jakobi and Chilibeck, 2001).

In addition to our findings, Koh and coworkers (1993) reported that correct pre-information did not influence the occurrence and magnitude of the BFD. Thus, available correct background information does not interfere with the physiological mechanisms of the BFD. Interestingly, Secher and colleagues (Secher et al., 1988) found an influence of incorrect pre-information on the BFD during leg press. In this study, initially higher BFD values around -20% were observed in a heterogeneous sample of trained and untrained adults. After completing these initial measures, the included participants were incorrectly briefed that the bilaterally produced force output should have been higher than the sum of unilaterally generated force output (inverse BFD explanation). As a consequence, the primarily observed BFD disappeared 5 weeks after the initial measures. Within 5 weeks, all participants had voluntarily access to the training and testing devices in order to familiarize. This procedure was unfortunately not standardized and controlled and the training-induced changes might have affected the BFD. Nevertheless, the bilaterally generated forces did not change between both measures compared to the notably lower unilateral force values. Thus, Secher and coworkers (Secher et al., 1988) assumed that these results might be caused by a volitional reduction of unilateral force production in order to meet the previously incorrectly given explanation of the BFD. In total, the applied study design of Secher and coworkers (1988) might not appraise this issue with certainty. Regarding the hypothesized underlying inhibitory neurophysiologic mechanisms, it would be of more interest if an incorrect pre-information (bilateral higher than unilateral) lead to comparatively higher bilaterally produced force values during post testing compared to pre-testing. Taking these considerations into account together with our findings, it is not likely that the assumed central and spinal neuro-physiological inhibitory mechanisms during bilateral leg-press might be altered by volitional and pre-informational (educational) modulations.

Since the BFD has been reliably observed in all conditions for nearly all subjects, it appears conceptionally reasonable to consider unilateral-alternating exercises especially in sports disciplines with alternating stroke patterns (e.g. running, swimming, cycling). Thus, conventional strength training using e.g. leg and bench press, squats, push- and chin-ups and dips (especially during specific training periods) are questionable in terms of sports-discipline specific motor patterns of strength requirements. It can be speculated, that this approach might be additionally useful in order to avoid overload-induced injuries during bilateral strength exercises and to enhance neuro-muscular properties by (alternating) unilaterally performed exercises with lower total weights on the spine or trunk. As these conclusions remain speculative and cannot be directly drawn from the present data with certainty, well-designed randomized-controlled intervention studies are needed to evaluate the effectiveness of unilateral vs. bilateral training on sport specific performance. Thereby, it appears not necessary to provide adequate background information on the theoretical basis of the BFD.

Nevertheless, some limitations of the present study need to be addressed. To apply all relevant pre-information conditions, we could have merely conducted a semi-randomized controlled study design. Although the strength tasks were randomly assigned, the days with pre-information had to be conducted after the initial test with NPI. We additionally did not measure EMG activity or assessed interpolated twitch techniques to achieve further insights into the phenomena of the BFD (e.g evaluating fatigue and potential declines of neuro-muscular activation). Such approaches might give more insights into the neuro-muscular time-course and basis of the BFD.

Conclusion

In line with previous studies, we can conclude that small but worthwhile BFDs have been repeatedly observed for almost all included participants in all condition. The availability of different pre-information does not relevantly influence the occurrence and magnitude of the BFD during isometric combined leg- and hip extension in young and trained adults. Thus, the BFD does not rely on the trueness of the given pre-information. Knowledge- or cognition-based volitional influences on the BFD on supra-spinal level seem to be negligible.

From a practical relevance view-point, visually supported instructions given prior to strength testing does not provide relevant potential to manipulate sensory-motor force expectations. However, further longitudinal research on the BFD would be beneficial in terms of addressing EMG-activity adaptation comparing both training approaches (bilateral vs. unilateral-alternation).

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Key points

- BFD is reliable occurring phenomenon
- Available theoretical knowledge does not affect the BFD
- Alternating sport should include alternating strength exercises

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