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Title Page

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Abstract

Purpose: A vertical jump (VJ) is a common task performed in several sports, with the height achieved correlated to skilled performance. Loaded VJs are often used in the training of recreational and professional athletes. The bilateral deficit (BLD), which refers to the difference between the heights achieved by a bilateral jump and the sum of two unilateral jumps, has not been reported for loaded jumps and the findings for unloaded jumps are inconclusive. The purpose of this study was threefold: (a) to quantify and compare BLD in countermovement (CMJ) and squat jumps (SJ), (b) to explore the effects of an additional 10% of body weight (BW) load on the BLD in both CMJ and SJ, and (c) examine the relationship between magnitude of BLD and jump performance in both jumps and conditions. **Methods**: Forty participants (20 for CMJ and 20 for SJ) performed a bilateral jump and unilateral jumps on each leg with and without an added load equivalent to 10% of each participant's bodyweight. **Results**: BLD was evident in all conditions, with CMJ BLD values nearly double those for the SJ. The extra load did not affect the magnitude of BLD. BLD had a significant correlation with unilateral jump height, expect for the 110%BW SJ. **Conclusions**: BLD is present in SJs and CMJs at both loaded and unloaded conditions. The SJs have about half of the BLD observed in CMJs regardless of additional load. Participants who had higher single leg jumps seemed to also have higher BLDs, but there was no evidence of association between the bilateral jump height and BLD.

Keywords: Performance, weighted-vest, asymmetry, biomechanics.

The term bilateral deficit (BLD) refers to reduction in the maximal output from a specific bilateral contraction, when compared to that of the combined outputs in similar unilateral contractions (Bobbert, de Graaf, Jonk, & Casius, 2006; Sale, 2003). A BLD has been examined and reported for several isometric maximal voluntary force tasks including: leg extension (Vandervoort, Sale, & Moroz, 1984), elbow flexion/extension (Taniguchi, 1998) and multi-finger key-pressing (Li, Zatsiorsky, Li, Danion, & Latash, 2001), as well as dynamic, explosive actions (Buckthorpe, Pain, & Folland, 2013; Hay, de Souza, & Fukashiro, 2006; Rejc, Lazzer, Antonutto, Isola, & di Prampero, 2010). A small number of studies (Bishop et al., 2019; Bobbert et al., 2006; Bracic, Supej, Peharec, Bacic, & Coh, 2010; Challis, 1998; Ebben, Flanagan, & Jensen, 2009) have examined BLD in a vertical jump using small to moderate sample sizes (N=7-12). Most of these studies reported a BLD with the unilateral jumps reaching a peak height of between 57-64% of the height of the bilateral jumps. Conversely, Ebben *et al.* (2009) reported a bilateral facilitation (BF), with the unilateral jumps only reaching approximately 45% of the height of the bilateral jumps. These authors suggested that their contradictory findings may be a function of training and sport-specificity, as their participants were primarily participating in throwing events, and it should also be noted that a single trial was used for each jump condition. Given the equivocal findings in this area, more research with large sample sizes is warranted to confirm the presence and extent of a possible phenomenon in vertical jumps (VJs).

Researchers speculate that BLD may be due to a multitude of possible mechanisms (for a review see Skarabot et al., 2016). For example, a reduction in neural drive has been proposed as the main cause of BLD when bilateral tasks are performed (Howard & Enoka, 1991; Post et al., 2007; Van Dieën, Ogita, & De Haan, 2003). Van Dieën et al. (2003) suggested that the reduction in neural drive is as a consequence of interhemispheric inhibition. Thus, the neural inhibition may be the underlying cause for the resultant BLD. Li et al. (2001) stated that the central nervous system seems to be unable to maximally, and simultaneously activate the larger number of muscles during bilateral tasks when compared to unilateral tasks. This reduction of neural activation is evident in reflexive contraction as well as in voluntary contraction, providing further substantive evidence for the contribution of neural factors in BLD (Kawakami, Sale, MacDougall, & Moroz, 1998; Khodiguian, Cornwell, Lares, DiCaprio, & Hawkins, 2003). Presence of BLD in dynamic, explosive actions is suggested to be due to the changes in the force that the lower concentric work per leg in the bilateral VJ task is predominately due to higher shortening velocities and perhaps a lower active state of the muscles compared to the unilateral VJs. It has been suggested that this was as a consequence of a change in force-velocity (F-v) relationship between the unilateral and bilateral jump conditions, as a higher total force output is generated in a unilateral VJ against the same resistive load experienced in a bilateral VJ (Bobbert et al., 2006; Buckthorpe et al., 2013; Samozino, Rejc, di Prampero, Belli, & Morin, 2014).

A VJ is a common task performed in several sports, with the height achieved often correlated to skilled performance (Cronin & Hansen, 2005; Girard & Millet, 2009). Currently, both professional and recreationally active athletes use loaded VJs as part of their exercise routine for the purpose of improving power output (Khlifa et al., 2010). Although there is currently no research on the effects of additional load on the BLD observed during VJs, it has been recently suggested that lower BLD values in jumping are related to performance in other explosive tasks such as the sprint start (Bracic et al., 2010), and that the magnitude of the BLD could be used to predict performance in these tasks. Nevertheless, potential links between the magnitude of BLD and performance outcomes may be different for other activities and should be explored further. For example, although Bracic et al. (2010) reported that lower BLD during a counter movement jump (CMJ) was linked to higher impulse and velocity of the blocks during sprint starts, Bishop et al. (2019) found that performance in a change of direction task was in fact linked to higher BLD. Further research in this area is therefore needed to provide more evidence regarding the existence and magnitude of BLD in VJs and its relationship to the performance of specific movement tasks. With the understanding that loaded VJs are normally executed at slower velocities than VJs without additional load (especially true of novice/non strength trained individuals) (Cormie, McBride, & McCaulley, 2009), identifying any changes in the magnitude of BLD associated with jumping with an additional load and/or the type of VJ performed (CMJ or squat jump (SJ)), would simultaneously enable a comparison of the effects of load on CMJ and SJ performance, and determine any relationships between BLD in body weight jumps and BL and UL jump performance in a loaded condition.

Therefore, the purpose of the present study was threefold: (a) to quantify and compare the BLD in CMJ and SJ of recreationally active participants, (b) to explore the effects of an additional 10% of body weight (BW) load on the magnitude of BLD in both CMJ and SJ, and (c) examine the relationship between occurrence/magnitude of BLD and jump performance in both the BW and 110%BW jump conditions.

Methods

Participants

Forty males volunteered to participate in this study. All participants were recreationally active, exercising for at least two sessions a week, on average, for a minimum of one year. Ethical approval was granted by the local institutional ethics committee. All participants were free from injury and illness and signed informed consent forms before participating in the study. The participants were randomly split into two groups, with one group performing the CMJs (CMJ group, N=22: 22.7±4.2 years, 179.5±7.3 cm, 78.5±17.2 kg) and the second group performing the SJs (SJ group, N=18: 24.4±7.3 years, 180.6±7.5 cm, 83.3±17.0 kg).

Experimental Design and Procedures

A cross-sectional experimental design was used to examine BLD in two vertical jumps commonly used in sports and training, a CMJ and a SJ. All participants performed three different versions of each jump: (a) bilateral jump; (b) unilateral jump taking off from the left leg (ULL), and; (c) unilateral jump taking off from the right leg (ULR). To explore the effects of loading on the magnitude of BLD, each vertical jump was performed under two conditions: (a) 'standard' condition where each participant had to jump against their body weight (BW), and (b) with an added load equivalent to 10% of each participant's body weight (110%BW). For the purpose of standardizing the vertical jumps, no arm swing was allowed and the depth was fixed.

All experimental procedures were explained to the participants before the date of testing. On the testing day, participants arrived in the laboratory and their height, body mass and age were recorded. The body mass value for each participant was used for the calculation of the 10% load that was added for the loaded condition. Each participant then performed a

10-minute standardized warm-up and practised a minimum of three vertical jumps of each type to familiarize themselves with the tasks. A separate familiarization session before the testing day was not deemed necessary, as previous studies have shown that this is not required with participants of this level (Moir, Shastri, & Connaboy, 2008).

In accordance with Challis (1998), the participants were instructed to put their hands on the waist during all jumps, and during the unilateral jumps to keep their free leg position fixed. For the SJs, the participants were instructed to squat until their thighs were parallel to the ground and maintain that position. On the researcher's signal, each participant performed a maximal vertical jump by moving upwards only. For the CMJs, the participants had to start standing with the trunk in an upright position and the legs straight. On the researcher's signal they had to perform the maximal jump in a continuous movement, by flexing the knees up to the position of the thighs being parallel to the ground and then extending the knees without pausing at maximum knee flexion. During the familiarization period, researchers measured the distance between the gluteal fold and the ground when each participant was in a squat position with thighs parallel to the ground. An adjustable device was used to determine the required height for each participant and the participants had to squat until the gluteus maximus touched the adjustable device. This measurement was used for all bilateral SJs and CMJs, to increase the consistency of jumps between participants and the reliability of squat depth. For the unilateral jumps. The same measurement was also used for unilateral jumps. It was however noted that it getting to the position of the thigh parallel to the ground was often challenging and did not allow the participants to produce a maximum jump. Hence, participants were instructed to go as deep as possible for the unilateral jumps (while still able to perform a maximum jump), but no deeper than the thigh parallel to the ground. The same device as above was then used to ensure consistency of depths among unilateral jumps. Two experienced researchers observed all jumps and if the depth was not achieved the jump was discarded and had to be repeated. Jumps also had to be repeated in the case of any arm action occurring during the jump, or any counter movement observed during a SJ. The above set-up appeared to facilitate production of the highest VJs for all conditions, but the depths used and any differences with depths used in other studies should be taken into consideration when interpreting and comparing results.

A 5-minute passive rest period followed the warm-up and familiarization. Each participant then performed three trials for each one of the following jumps in a randomized order: ULL jump, ULR jump, bilateral jump. Thirty seconds were allowed between each set of three trials, and a five-minute passive rest period was provided between different sets of trials. The same jumps were performed with a 10%BW load added on each participant with the use of a weighted vest (Reebok, Ironwear). Half of the participants in each jump group performed the BW conditions first, with the other half performing the loaded condition first (using an ordered block procedure).

For all jumps peak height was measured with the use of a jump mat (Just Jump, Alabama). The highest jump of the three trials for each condition was used for subsequent analysis. The Just Jump mat calculates jump height from the flight time (time in the air) using the following formula:

$$\frac{t^2 \times g}{8} \quad (1)$$

where, t = time in the air, and g = 9.81m.s^{-2}.

When using such devices, if the time in the air is extended by, for example, excessive knee bent before touch-down, jump height may be overestimated (Moir et al., 2013). For that reason, participants were instructed to have the legs straight at first contact with the ground, for consistency with the take-off position. If any jumps did not fit this criterion they were discarded and participants were asked to repeat them.

The sum of the left and right unilateral jumps (ULS) was calculated and compared with the bilateral jump height. To quantify BLD the following formula was used (Rejc et al., 2010):

$$BLD = (1 - \frac{BLH}{ULS}) \times 100 \qquad (2)$$

where, ULS is the sum of unilateral jump heights and BLH is the bilateral jump height. A positive number would indicate a BLD, with a negative number indicating bilateral facilitation.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for Social Sciences 16.0 (SPSS Inc, Chicago, 2005). Measures of central tendency and spread of the data were reported as means and standard deviations. The Shapiro-Wilk test was used to assess normality of distribution for all data. Depending on the results of the Shapiro-Wilk test either Student's *t*-test (independent or paired) or Wilcoxon's signed rank test was used to determine any statistically significant differences between sets of parametric or non-parametric data, respectively.

Prior to analyzing the respective jump data, comparisons examining the order in which the respective jumps (SJ and CMJ) were performed (BW then 110%BW or 110%BW then BW) were conducted for ULS, BLH and BLD data, to identify if the order of load conditions affected either BLD or the peak jump height reached. A paired sample t-test was used to compare the ULS and BLH for the BW and 110%BW jumps. The BLD was then compared between BW and 110%BW conditions, to identify any effects of load on the magnitude of BLD in both SJ and CMJ. The jump height data (ULL, ULR, ULS, ULH) data were compared using the Wilcoxon signed-rank test. To provide an indication of the magnitude of the differences, the effect sizes (*d*) for all the statistically significant differences were calculated based on Cohen's suggestions, with each pooled SD being calculated (Cohen, 1988). In line with Cohen's recommendations, effect sizes of a magnitude of 0.2, 0.5 and 0.8 were considered small, moderate and large, respectively.

To examine differences in BLD as a consequence of the participants' jumping ability, the bilateral SJ and CMJ height data were rank ordered and a split performed, separating the BLD data into three groups (high – top 1/3, middle 1/3, and low – bottom 1/3 jumpers) for each condition (SJ – BW and 110%BW and CMJ – BW and 110%BW). Bilateral jump height data was used to order and split the groups as this is the more commonly used measure of athletic performance. Independent samples t-tests were performed to compare the BLD observed in high and low jumpers for each condition. Additionally, for both SJ and CMJ data the percentage difference between BLD observed in the BW and 110%BW was calculated, and the same split protocol undertaken to enable an investigation of the effects of jump ability on the change in BLD and examine if better (top 1/3) jumpers increased, maintained or decreased BLD in the 110%BW condition, and were responded differently to the increase in load compared to bottom 1/3 of jumpers. Pearson correlation coefficients were used to determine the interrelationships among the unilateral and bilateral jump heights and the BLD between the BW and 110%BW conditions, within both the SJ and CMJ. Correlation values of

0.20-0.39, 0.40-0.59, 0.60-0.79, and ≥0.80 were considered as low, moderate, moderately high, and high, respectively. Significance for all variables was set at $p<0.05$ *a priori*.

Results

Table 1 shows the peak height achieved with each jump type, as well as the magnitude of BLD observed between unilateral and bilateral jumps. Figures 1 and 2 show the individual BLD values for all participants in this study. Comparisons examining the order in which the jumps were performed revealed no significant differences for either BLD or the peak height reached in any of the jumps. This indicated that the order in which the jump conditions were performed had no effect on the results of this study.

The ULS was significantly greater ($p<0.001$) than the BLH for all jump types and for both the BW and loaded conditions, and the effect sizes were generally large (Table 1). A BLD was evident in all conditions, with the ULS being between 18.7-19.2% greater than the BLH for the CMJs and between 10.6-11.9% greater than the BLH for the SJs. Out of the 40 participants tested and the 80 comparisons made there were only 3 incidents of BF, one for a non-loaded and two for loaded SJs.

Insert Table 1 and Figures 1 and 2 about here

The extra load did not appear to affect the magnitude of BLD, as there were no statistically significant differences between the BW and 110%BW in any of the jump conditions. On the contrary, the type of jump seemed to have an effect on the magnitude of BLD, as the BLD in the CMJs were nearly double the values for the SJs in both the BW (p=0.003, *d*=0.98) and loaded conditions (*p*=0.003, *d*=1.01). Finally, as expected, the CMJ produced higher peak height compared to the SJ for all conditions (p<0.001, 1.48≤d≤2.05).

BLD data (Table 2) showed that the bottom 1/3 of jumpers (by rank ordered height jumped) had approximately half the BLD of that of the top 1/3 of jumpers, in the SJ and the 110%BW SJ, with mean difference of 7.0% and 6.4% respectively. The change in BLD with the additional of the 10%BW load between the top 1/3 and the bottom 1/3 of jumpers in both SJ and CMJ revealed there to be no statistically significant differences.

Insert Table 2 about here

No statistically significant differences were found between the top and bottom third of jumpers in the percentage change in BLD between the BW and 110%BW conditions for either CMJ or SJ (Table 3).

Insert Table 3 about here

The BLD in both SJ and CMJ demonstrated moderately high correlations between the BW and 110%BW conditions (Table 4). Moderately high to high correlations were observed between the BLH and all three of ULL, ULR and ULS in both jumps and weighted non-weighted conditions. This indicated a positive relationship between the maximal UL and BL jump heights. In addition, moderate to moderately high correlations were found between the BLD and all three of the ULL, ULR and ULS, in the BW SJ and CMJ. Conversely, there were no significant correlations between BW BLH and both BW BLD and 110%BW BLD in SJ and CMJ. Finally, a moderate correlation between BW BLD and 110%BW BLH was found in the SJ.

Insert Table 4 about here

Discussion

With the evidence regarding the existence and magnitude of BLD in vertical jumps being equivocal, the purpose of the present study was to add evidence to the body of literature that would help clarify the extent of this phenomenon in both CMJs and SJs. This study also aimed to explore if an additional 10%BW load would have any effects on the BLD observed, and if the magnitude of BLD is related to vertical jump performance or affected by the order of testing. There was a clear indication of substantial BLD in all jumps and load conditions. The BLD in CMJs was nearly twice as much as BLD in SJs, with the added load or order of testing not significantly affecting the magnitude of BLD observed. Contrary to previous suggestions, jump performance was not associated with lower BLD values.

The initial aim of the present study was to quantify and compare the BLD in CMJ and SJ of recreationally active participants. The mean BLD recorded in the unloaded SJs jumps in the present study (11.9%) was similar to that reported by Challis (1998) (12.9%) and Bobbert et al. (2006) (14.1%). It is worth noting that the participants in the latter studies had not been asked to reach a specific knee angle when squatting, with the bilateral jumps then designed to replicate the angle used in the unilateral jumps that were performed first. In the present study, all jumps were standardized to a position of thighs parallel to the ground, which resulted in larger knee flexions that the above studies. The similarity of BLD values among all three studies suggests that the different depths of SJs did seem to affect BLD magnitude.

The magnitude of BLD for unloaded CMJs in the present study (19.2%) was substantially higher than the BLD reported for SJs in the present and in previous studies, and nearly identical to the value reported for CMJs by Bracic et al. (2010) (19.1%). This suggests that the BLD for CMJs is substantially higher than that for SJs. The higher BLD observed in CMJs may be explained by the difference in the performance requirements and the relative complexity of performing the SJ compared to the CMJ, as also suggested by the relative differences between unilateral and bilateral jump performance across the two conditions (SJ vs CMJ) in the present study. The SJ group seemed to be poorer in the unilateral condition, as there was a proportionally lower discrepancy in the attained BLH between the CMJ and the SJ condition (SJ BLH 81.4% of CMJ BLH) when compared to the jump height values in ULS achieved (SJ ULS 76.1% of CMJ ULS). This implies that the relative complexity of, and/or lack of familiarity with the unilateral SJ compared to bilateral SJ, is greater than in the unilateral CMJ when compared to the bilateral CMJ. Factors such as the requirement to pause and maintain a stable position in the unilateral SJ condition, requiring additional balance/postural control abilities, may limit the expression of maximal levels of force in the unilateral SJ. Bobbert, Gerritsen, Litjens, & Van Soest (1996) suggested that the relatively poor performance in the SJ occurs as a consequence of a reduced ability to optimally adapt the coordination and control of the jumping movements in response to the altered initial conditions (static pose) in the SJ. Given that Bobbert et al. (1996) was referring to the differences in bilateral jumping conditions (CMJ vs SJ), and that the unilateral nature of the unilateral jumping task only further challenges the postural control systems, the discrepancy in unilateral jumping may be even greater, as shown in the present study.

Another possible reason for the differences in BLD may be the training and experience the participants have in jumping. The participants in the CMJ studies were recreationally active participants (present study) and elite sprinters (Bracic et al., 2010), while the participants in the SJ studies were participating in sports such as basketball, volleyball and gymnastics and had substantial jumping experience and training. Howard & Enoka (1991) suggested that discrepancies in the magnitude of BLD may exist due to differences in the training status of participants, with trained participants able to reduce or eliminate the occurrence of BLD.

One may also speculate that differences in the BLD between the CMJs and SJs may be related to the overall height achieved by participants. Participants in the present study reached a 0.54m BLH for CMJ, which was similar to that reached by those in the Bracic et al. (2010) study (0.6m) and much higher than the BLH for SJs reported by Challis (1998) and Bobbert et al. (2006) (0.17m and 0.28m, respectively), as well as for the SJs in the present study (0.44m). Nevertheless, the SJs in the present study were still substantially higher than those in previous studies but resulted in overall similar BLD values, suggesting that the actual height reached would not be the primary reason for differences in BLD. A more in-depth mechanistic analysis, in which jump phases can be quantified and compared, may be useful in understanding this relationship.

The second aim of the present study was to explore the effect(s) of an additional 10% of BW load on the magnitude of BLD in both CMJ and SJ. The additional load appeared to reduce unilateral and bilateral jumps in both types of jumps, but there was no significant difference in BLD between the BW and 110%BW conditions. This suggests that any reductions in the muscle shortening velocity during the loaded jumps and, perhaps, the force produced by the muscles, did not affect the magnitude of BLD observed in SJ or CMJ. Loaded vertical jumps at 110%BW could therefore be performed by athletes and other professionals without any changes in BLD. As the actual angular velocities during the jumps and the effects of loads larger than 110% BW were not assessed in the present study, research on a wider range of added loads is warranted to provide further information on the effects of loading on BLD magnitude. While there was a marked difference in the magnitude of the BLD between the Top and Bottom 1/3 of the jumpers in the SJ for both BW and 110%BW conditions (with poorer jumpers having a lower BLD), comparisons of BLD between the best and worst jumpers in each group (Table 2) revealed no statistically significant differences between either the CMJ or SJ in either load condition.

The third and final aim of the present study was to examine any relationships between the occurrence and magnitude of BLD and jump performance in both the BW and 110%BW jump conditions. Unsurprisingly, there were strong relationships between UL and BL jump heights in both the SJ and CMJ (Table 4), indicating that the ability to jump high in a unilateral stance is strongly related to the ability jump high in a bilateral stance (irrespective of jump type). The strong relationship in BLD between the BW and 110%BW conditions for both SJ and CMJ, demonstrates that irrespective of a change in task demands (+10%BW) the respective BLD remains relatively consistent, with participants who had a high BLD in the BW condition likely to have a relatively high BLD in the 110%BW condition in both SJ and CMJ.

Previous research highlighted the potential relationships between the occurrence of a BLD and levels of performance measures in a sprint start task in elite sprinters, demonstrating that sprinters with a lower BLD produced greater total impulse on the blocks and higher velocity values as they leave the blocks, during a sprint start (Bracic et al., 2010). The VJ is a common task performed in several sports, with the height achieved consistently shown to be highly correlated with skilled performance (Cronin & Hansen, 2005; Girard & Millet, 2009). If the proposition by Bracic et al. (2010) that the BLD evident in a VJ task is also related to and can predict skilled performance in explosive tasks is correct, then this would have important practical implications on the relationships between BLD, performance and training practice specifically designed to influence the occurrence of BLD. However, unlike Bracic et al., the BLD observed in the BW CMJs did not relate to the performance of the associated performance task (CMJ BLH in the 110%BW condition (r = 0.043), irrespective of the higher degree of biomechanical similarity between the BLD task and the performance task (CMJ +10BW) in the present study. The SJ group did however, show a moderate association (r = 0.517) between SJ BLD and SJ BLH in the 110% BW load condition, suggesting that the BLD which occurred in the unloaded jumps was related to the BLH achieved. However, in contrast to Bracic *et al.* (2010), where reduced BLD was related to better sprint start performance, the present data showed that as the BLD apparent in the SJ condition increased so did the maximum BLH in the 110% BW load condition. Given the increased biomechanical similarity of the performance task to the jump task in the present study (compared to that employed in the Bracic et al. study), it may have been expected that if the relationship proposed by Bracic *et al.* between the magnitude of BLD and its relationship to other explosive performance held true, that a similar relationship would also be apparent within the data from the present study. However, there was no evidence in the data to confirm this assumption. On the contrary, participants with larger BLD also achieved larger heights in UL jumps (except the SJ 110% condition). Bishop et al. (2019) reported that higher BLD in CMJs was linked to shorter times for a change of direction test, but no other links were find between BLD and 30m or 50m sprint times. These authors speculated that higher unilateral competence may be beneficial in tasks with unilateral movement patterns such as the change of direction task, but could perhaps be less important in bilateral tasks. In line with this, and although cause and effect in the current study cannot be determined, our findings may suggest that when performance relies on unilateral tasks it may even be beneficial for coaches to attempt to increase the BLD and to focus more on unilateral training. This suggestion warrants further investigation, together with exploration of causality and the possible mechanics for this phenomenon, to allow confirmation and generalization of such practical applications.

What does this article add?

The present study included a much larger sample size than previous dynamic BLD research, providing evidence that a BLD does exist when performing SJs and CMJs. The study expanded on previous research by including an extra condition of 10% added load. This had not been studied before and has important implications not only for athletes but also for tactical-athletes performing loaded jumps for their training and duties. We showed that a BLD of similar magnitude exists also in loaded jumps. Finally, this article did not find any evidence to suggest that jump performance is linked to lower BLD. On the contrary, a larger BLD was associated with higher UL jump heights, except for the loaded SJ condition. Training status and specificity may be more important factors than jump performance when athletes aim to maximize their BLH based on their unilateral jumping abilities.

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Tables

Table 1: Mean ±SD (m) of maximum jump height for left leg unilateral (ULL) jumps, right leg unilateral ULR) jumps, sum of left and right leg unilateral jumps (ULS), bilateral jumps (BLH). Bilateral deficit (BLD) between ULS and BLH is expressed as a percentage.

Jump Type	ULL	ULR	ULS	BLH	BLD
CMJ	0.34±0.05[b]	0.34±0.04[b]	0.67±0.08[a,b] (*d*=1.87)	0.54±0.05[b]	19.2±6.5%[b]
CMJ-110%BW	0.30±0.05[b]	0.30±0.04[b]	0.60±0.08[a,b] (*d*=1.75)	0.48±0.05[b]	18.7±8.0% [b]
SJ	0.26±0.05	0.25±0.05	0.51±0.09[a] (*d*=0.86)	0.44±0.06	11.9±8.2%
SJ-110%BW	0.23±0.04	0.23±0.04	0.46±0.08[a] (*d*=0.77)	0.41±0.06	10.6±8.0%

[a] Significantly different to BLH for the same jump at $p<0.001$ (effect sizes shown in parentheses).
[b] Significantly different to the same variable for the SJ

Table 2: Mean ±SD of percentage BLD of the highest one third (Top ⅓) and lowest one third (Bottom ⅓) of the ranked order jump heights for SJ and CMJ

Jump type	**Top ⅓**	**Bottom ⅓**	***p*-value**
CMJ*	17.1±5.9%	18.0±6.8%	0.782
CMJ +110%BW*	16.6±7.9%	18.3±8.2%	0.704
SJ[†]	15.0±6.9%	8.0±9.9%	0.150
SJ +110%BW[†]	14.1±6.6%	7.7±8.9%	0.187

*Top seven and bottom seven included in the analysis

[†]Top six and bottom six subjects included in the analysis

Table 3: Differences in (Mean ±SD) percentage change in BLD (**%** ΔBLD) between BW and 110%BW conditions for the highest one third (Top ⅓) and lowest one third (Bottom ⅓) of the ranked order jump heights for SJ and CMJ

Jump Type	Top ⅓ -% ΔBLD	Bottom ⅓ -% ΔBLD	*p*-value
CMJ: BW-110%BW	-0.45±7.4%	0.25±3.1%	0.819
SJ: BW-110%BW	-0.86±5.3%	-1.45±9.7%	0.777

Table 4: Pearson Correlation Coefficient data: Relationships between jump height and bilateral deficit data.

		SJ BLD - BW		**SJ BLH - BW**		**SJ BLD - 110%BW**		**SJ BLH - 110%BW**	
SJ BW		*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
	ULL	0.745	<0.001	0.876	<0.001	0.368	0.133	0.845	<0.001
	ULR	0.703	0.001	0.881	<0.001	0.419	0.084	0.866	<0.001
	ULS	0.740	<0.001	0.896	<0.001	0.419	0.084	0.873	<0.001
	BLH	0.376	0.124	.	.	0.171	0.498	0.871	<0.001
	BLD	.	.	.	.	0.596	0.009	0.503	0.033

		CMJ BLD - BW		**CMJ BLH - BW**		**CMJ BLD-110%BW**		**CMJ BLH - 110%BW**	
CMJ BW		*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
	ULL	0.589	0.004	0.764	<0.001	0.478	0.024	0.714	<0.001
	ULR	0.618	0.002	0.713	<0.001	0.518	0.014	0.759	<0.001
	ULS	0.621	0.002	0.766	<0.001	0.511	0.015	0.757	<0.001
	BLH	-0.025	0.912	.	.	0.033	0.884	0.916	<0.001
	BLD	.	.	.	.	0.770	<0.001	0.060	0.791

Figures

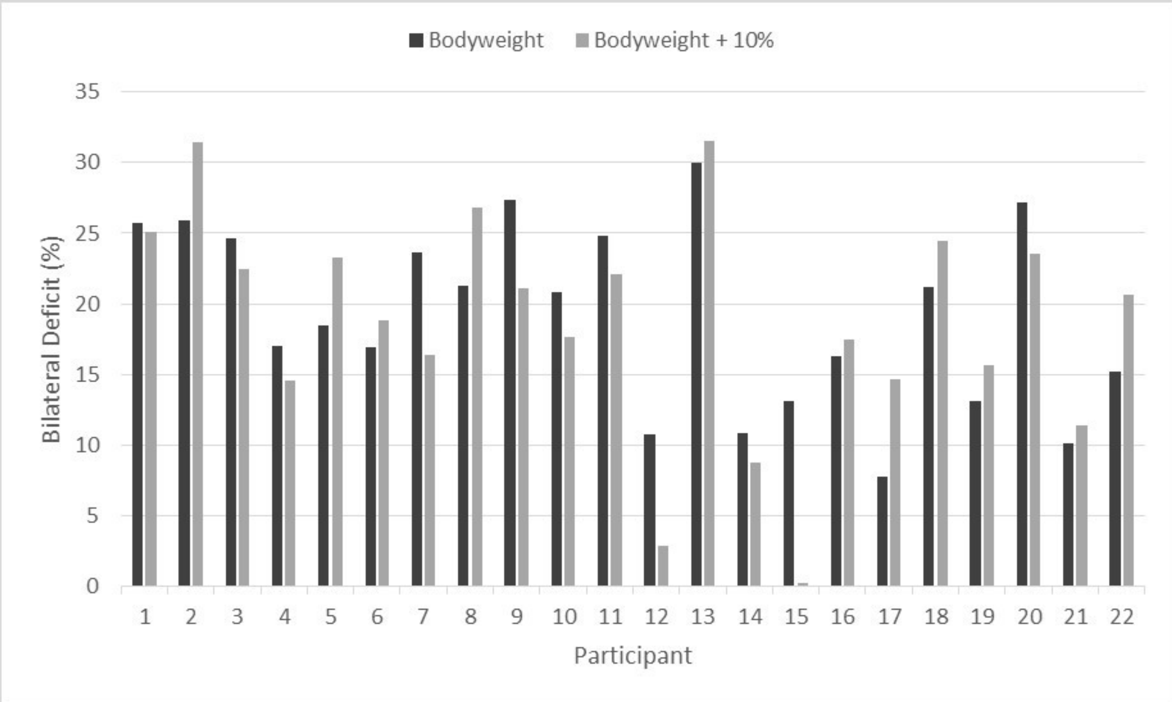

Figure 1: Bilateral deficit for all participants performing the countermovement jump with and without added load.

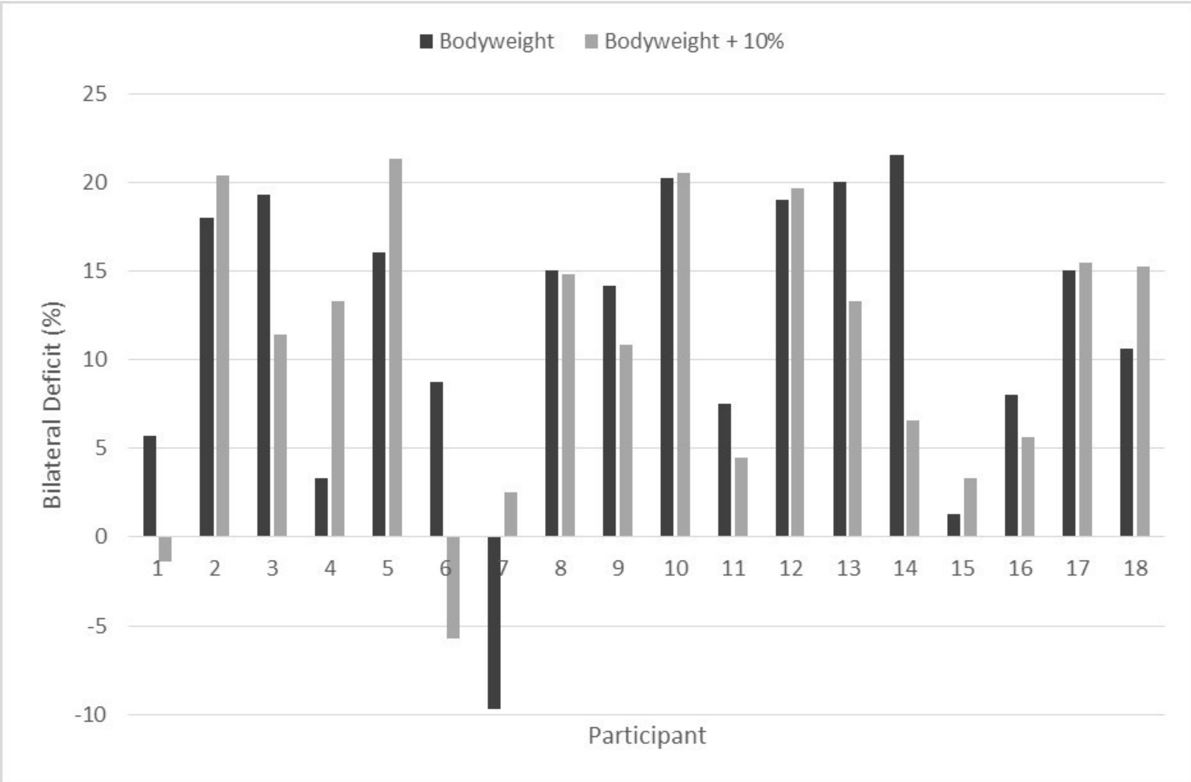

Figure 2: Bilateral deficit for all participants performing the squat jump with and without added load.