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Effect of stable and unstable loads on post-activation performance enhancement in the countermovement jump

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ABSTRACT

This study aimed to investigate the practicality of unstable loads and their effect on post-activation performance enhancement (PAPE), observed through force time kinematic variables in the countermovement jump (CMJ). Thirty-four collegiate male athletes participated in a randomized crossover experiment. Athletes were randomly assigned to first complete either the 20.4 kg barbell stable (ST) or 20.4 kg water bag unstable (US) load protocol After a 20-minute rest period, the subjects completed the other protocol. Protocols consisted of a baseline jump, two sets of three consecutive jumps with the load, then a second jump to retest. Force plate data were sampled at 1,000 Hz and predetermined landmarks of the force time curve were utilized to calculate key performance indicators. A two-way repeated measures ANOVA with condition (ST, US) and time (pre, post) as independent variables was used to assess outcome variables. Statistical significance was set at $p < .05$. No significant interaction or condition effects were present in findings ($p > .05$). Peak and average braking force ($p = .001$; $p < .001$ respectively), braking impulse ($p < .001$), takeoff velocity ($p = .005$), jump height ($p = .006$), center of mass (COM) depth ($p = .006$), and rate of force development (RFD) ($p = .009$) were all significantly different between the first and second jump for both ST and US conditions. The results of this study suggest that either stable or unstable loads may produce a PAPE effect, thus increasing the number of modalities available to achieve this outcome.

Keywords: water bag, force-time, jump kinematics, instability training

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1. Introduction

One method to improve performance in an acute setting is through the use of validated strategies to promote post-activation performance enhancement (PAPE). In a review conducted by Blazevich and Babault (2019), they reported that three of the most well documented ways in accomplishing PAPE are through increases in muscle temperature, muscle blood flow, and muscle activation primed through neural drive. This is not to be confused with post-activation potentiation (PAP), a term that once also encapsulated short-term performance increases until a recent differentiation proposed in 2017 by Cuenca-Fernández and colleagues (2017) categorized the two separately. Now, the definition for PAP stands as the result of action potentials on the muscle membrane that stimulate calcium ions in the sarcoplasmic reticulum to facilitate muscular contractions that were signaled through prior voluntary contractions and/or electrical stimulation (Rassier & MacIntosh, 2000; Sale, 2002; Sweeney et al., 1993); and though it is a byproduct of voluntary muscular contractions, the increased saturation of Ca^{2+} ions alone do not seem to play a factor in increased performance (Smith & Fry, 2007). Additionally, the effects of PAP are observed for mere seconds to a few minutes, while the effects of PAPE can be observed for an appreciably longer amount of time (Wilson et al., 2013).

Recent literature has looked deeper into stimulus modalities that can maximally increase acute performance in activities such as the countermovement jump (CMJ). There are a number of force-time variables within the jump that can be observed through force plates that would indicate PAPE being actuated. Beato and colleagues (2021) investigated the use of eccentric overload on PAPE by measuring jump height, peak power, impulse, and peak force at multiple time points post intervention and had observed significant differences between the control and experimental groups from the 3 through 9 minute timestamps. Another study conducted by Sirieiro and colleagues (2021) manipulated load and rest times and observed how these variables affected PAPE in the CMJ. Four different conditions were utilized in a half squat programmed off a five-repetition max. They consisted of a maximal load, a 65% load, and the other two conditions used the same loads but included an inter-set rest. A bar speed tracker was used to ensure maximal intent was performed each rep. Their findings concluded that working at heavier loads in a traditional manner had a significant effect on PAPE through jump height, rather than the other three conditions which displayed minor improvements. One modality with respect to PAPE with minimal evidence is the implementation of

instability, which can exist as both an unstable surface and/or an unstable load.

More often than not, instability implementation references an unstable surface. Current literature in an acute setting has observed force production decreasing by levels greater than 30% when performing exercises on unstable surfaces (Drinkwater et al., 2007; Saeterbakken & Fimland, 2013). When investigating their effect on PAPE, these findings remain consistent as they did not outperform their stable counterparts in the CMJ (Cardona Gómez & Rojas Jaramillo, 2025; Simonelli et al., 2024). At this moment, little data exist in regard to unstable loads and their effect on acute changes in performance, including force production. Most of the current literature that does exist pertains to electromyography and muscle activation on primary movers and muscles classified as stabilizers. Research to this point has yielded similar findings to that of unstable surfaces in that there is greater recruitment of the musculature in the trunk and distal muscles of the leg, specifically in the soleus, gluteus medius, and transverse abdominus (Lawrence & Carlson, 2015; Wezenbeek et al., 2022). To this point, only one study, conducted by Jirovska and colleagues (2023), did test a stable and unstable load, via a squat, and its effect on a subsequent CMJ, but found no data of significance in jump height, peak concentric power, and peak rate of force development. Currently there is no literature that has utilized stable and unstable loaded plyometrics while evaluating their effects via the CMJ.

With the relative novelty to unstable load training via water bags, this study aimed to determine the effects of how stable and unstable loads affect post activation performance enhancement through the CMJ force-time curves and kinematic variables.

2. Methods

• *Experimental Approach to the Problem*

A randomized crossover experiment was utilized to determine whether differences existed between stable and unstable loading conditions in regard to their potential PAPE effects. Kinematic variables measured from a CMJ were calculated to determine these effects.

• *Subjects*

A total of 36 collegiate male athletes (age 20.44 ± 1.69 yrs; height 1.84 ± .09 m; mass 90.94 ± 13.27 kg) were recruited for this study, two of which were dismissed after participating for having invalid data, leaving a total of 34

participants for full analysis. To qualify for participation, athletes needed to be a current NCAA, NJCAA, or NAIA athlete and in good health, meaning they were not recovering from an injury within the last year that would affect their performance. Additionally, the athlete had to have a resistance training age of at least one year. Athletes were instructed to avoid strenuous and high intensity activity prior to the experiment on that calendar day. This research was approved by the university's Institutional Review Board. All procedures were conducted according to the Declaration of Helsinki for studies involving human subjects. All subjects completed the informed consent process prior to study participation.

• ***Procedures***

Subjects began the protocol by going through a light warm up, that consisted of walking on a treadmill at 5 km/h for 5 minutes. No movements were done prior that would have potentiated the CMJ from similar neuromechanical patterning, like bodyweight squats or lunges. Once finished, participants were randomly assigned to either the stable (ST) or unstable (US) condition, which would signify the protocol to be completed first. Both protocols were identical in structure with recording a baseline CMJ on force plates. Baseline jumps were then followed by two sets of squat jumps with either the stable (standard 20.4kg barbell) or unstable (20.4kg water bag) (Tidal Tank, Beaumont, TX, USA) load (Figure 1, Figure 2). Each set consisted of three consecutive jumps with 90-seconds of rest between sets. Both loads were positioned on the subjects' upper back, similar to a high bar back squat, when performing the jumps. Following completion of the two sets under the assigned condition, CMJ performance was re-tested on the force plates. After the post-intervention CMJs, a twenty minute break was taken before the subject performed the other study condition. This break was employed to minimize the carryover effect from the current PAPE leading into the next condition (Wilson et al., 2013). At the end of the break, participants underwent the same protocol with the other intervention, excluding the five-minute warmup.



Figure 1. sable load



Figure 2. Unstable load

- ***Countermovement Jump***

CMJ performance was assessed using a pair of GRF plates (PASCO PS-2141, Roseville, GA, USA). Participants were instructed to stand in an athletic position with one foot fully on each plate. Following a countdown by the researcher, subjects performed a maximal CMJ with their hands on their hips. Subjects were instructed to jump as high as possible. CMJ data collection was ceased following the successful landing of the subject. All GRF data were sampled at a frequency of 1000Hz and then exported to a .csv file and subsequent calculations were completed through a custom MatLab script (Mathworks, Natick, MA, USA).

• ***Data Analysis***

Identification of countermovement jump phases and force-time calculations followed methods described by McMahon et al. (2018) and Chavda et al. (2018). The weighing phase used 1 second of quiet standing to calculate the subject's bodyweight. Mass was calculated from bodyweight. The unweighting phase began at the onset of movement, calculated as 30 milliseconds prior to the time the vGRF was 5SD less than bodyweight (Owen et al., 2014). This phase ended at the instant force equaled bodyweight. The braking phase began at the end of the unweighting phase. The end of the braking phase was defined as the instant velocity equaled zero. The propulsion phase began at the end of the braking phase and ended at the instant of take-off. The end of the propulsion phase (take-off) was defined as the instant vertical ground reaction force was less than 5SD of a 300 ms portion of the flight vGRF (Lake & McMahon, 2018). The flight phase was defined as the end of the propulsion phase to the start of the landing phase. The landing phase began at the instant vGRF was greater than 5SD of a 300 ms portion of the flight vGRF (Lake & McMahon, 2018). The landing phase ended when the velocity of the center of mass was equal to zero.

The following metrics were calculated for analysis as outcome variables: takeoff velocity, jump height, mean braking force, braking net impulse, mean propulsive force, propulsive net impulse, braking phase rate of force development, center of mass (COM) depth, time to takeoff, braking phase duration, and propulsive phase duration. Jump height was calculated using the takeoff velocity method. Net force was calculated as the vGRF minus bodyweight. Net impulse was calculated by integrating the area under the net force-time curve. Velocity was calculated by integrating the acceleration-time curve. COM displacement was calculated as the integration of velocity over time.

• ***Statistical Analysis***

Mean and standard deviation are presented for each variable. Data were checked for normality using Shapiro-Wilk test and visual inspection of Q-Q residual plots. A two-way repeated measures ANOVA with condition (ST, US) and time (pre, post) as independent variables was used to assess outcome variables. Statistical significance was set at $p < .05$. Effect sizes were calculated as partial eta squared, and interpreted as small = 0.01, moderate = 0.06, and large = 0.14. All statistical analyses were performed using JASP (version 0.19.2).

3. RESULTS

There were no observed interaction effects in any of the performance metrics ($p > .05$). Moreover, there were no significant condition main effects ($p > .05$). Main effects for time are presented in Table 1. No significant main effects for time were found for mean propulsive force ($F(1,33) = 1.24$, $p = 0.27$), time to takeoff ($F(1,33) = 2.06$, $p = 0.16$), or braking phase duration ($F(1,33) = 2.19$, $p = 0.14$).

Both conditions exhibited significant changes from pre- to post-intervention in a variety of CMJ outcomes. Takeoff velocity ($F(1,33) = 8.98$, $p = 0.005$, $\eta_p^2 = 0.214$) and jump height ($F(1,33) = 8.75$, $p = 0.006$, $\eta_p^2 = 0.210$) were significantly higher in the post-intervention jump in both conditions. Both groups also exhibited significant changes from pre- to post-jumps in mean braking force ($F(1,33) = 16.17$, $p < 0.001$, $\eta_p^2 = 0.329$) and braking net impulse ($F(1,33) = 23.43$, $p < 0.001$, $\eta_p^2 = 0.415$), both with large effect sizes. Propulsive duration ($F(1,33) = 6.47$, $p = 0.016$, $\eta_p^2 = 0.164$) and propulsive net impulse ($F(1,33) = 8.69$, $p = 0.006$, $\eta_p^2 = 0.208$), were significantly greater in both conditions. Countermovement depth was greater after the intervention ($F(1,33) = 8.53$, $p = 0.006$, $\eta_p^2 = 0.205$). Braking phase rate of force development was greater following the intervention ($F(1,33) = 7.27$, $p = 0.011$, $\eta_p^2 = 0.180$). While no statistically significant interaction was observed for takeoff velocity ($p = 0.09$), the effect size was moderate ($\eta_p^2 = 0.090$). While no statistically significant interaction was observed for propulsive net impulse ($p = 0.078$), the effect size was moderate ($\eta_p^2 = 0.091$). Force time curves are presented in Figure 3.

Table 1. Jump height and force-time characteristics

	Stable		Unstable		Time		Condition		Interaction	
Variables	Pre	Post	Pre	Post	p	η_p^2	p	η_p^2	p	η_p^2
Jump height (m)	0.342 ± 0.083	0.348 ± 0.071	0.335 ± 0.068	0.360 ± 0.063	0.006	0.210	0.639	0.007	0.066	0.098
Takeoff velocity (m/s)	2.57 ± 0.34	2.60 ± 0.28	2.55 ± 0.26	2.65 ± 0.24	0.005	0.214	0.472	0.016	0.090	0.085

Mean braking force (N)	1351 ± 203	1417 ± 242	1359 ± 191	1429 ± 256	<0.001	0.329	0.603	0.008	0.850	0.001
Braking net impulse (Ns)	92 ± 22	100 ± 26	91 ± 23	102 ± 24	<0.001	0.415	0.887	<0.001	0.811	0.024
Mean propulsive force (N)	1769 ± 201	1774 ± 207	1769 ± 226	1788 ± 247	0.274	0.036	0.662	0.006	0.342	0.027
Propulsive net impulse (Ns)	229 ± 28	232 ± 25	227 ± 27	237 ± 27	0.006	0.208	0.473	0.016	0.078	0.091
COM depth (m)	-0.299 ± 0.078	-0.325 ± 0.086	-0.314 ± 0.072	-0.330 ± 0.074	0.006	0.205	0.280	0.035	0.499	0.014
Time to takeoff (s)	.889 ± .125	.875 ± .115	.892 ± .145	.871 ± 117	0.161	0.059	0.936	<.001	0.645	0.007
Braking phase (% of time to takeoff)	24.0 ± 4.6	23.0 ± 3.9	23.2 ± 4.7	22.7 ± 3.7	0.148	0.062	0.352	0.026	0.613	0.008
Propulsive phase (% of time to takeoff)	30.0 ± 3.7	30.5 ± 3.5	29.9 ± 4.0	31.0 ± 3.4	0.016	0.164	0.696	0.005	0.393	0.022
Rate of force development braking phase (N/s)	4351 ± 2143	4976 ± 2399	4701 ± 2189	5111 ± 2677	0.011	0.180	0.350	0.027	0.552	0.011

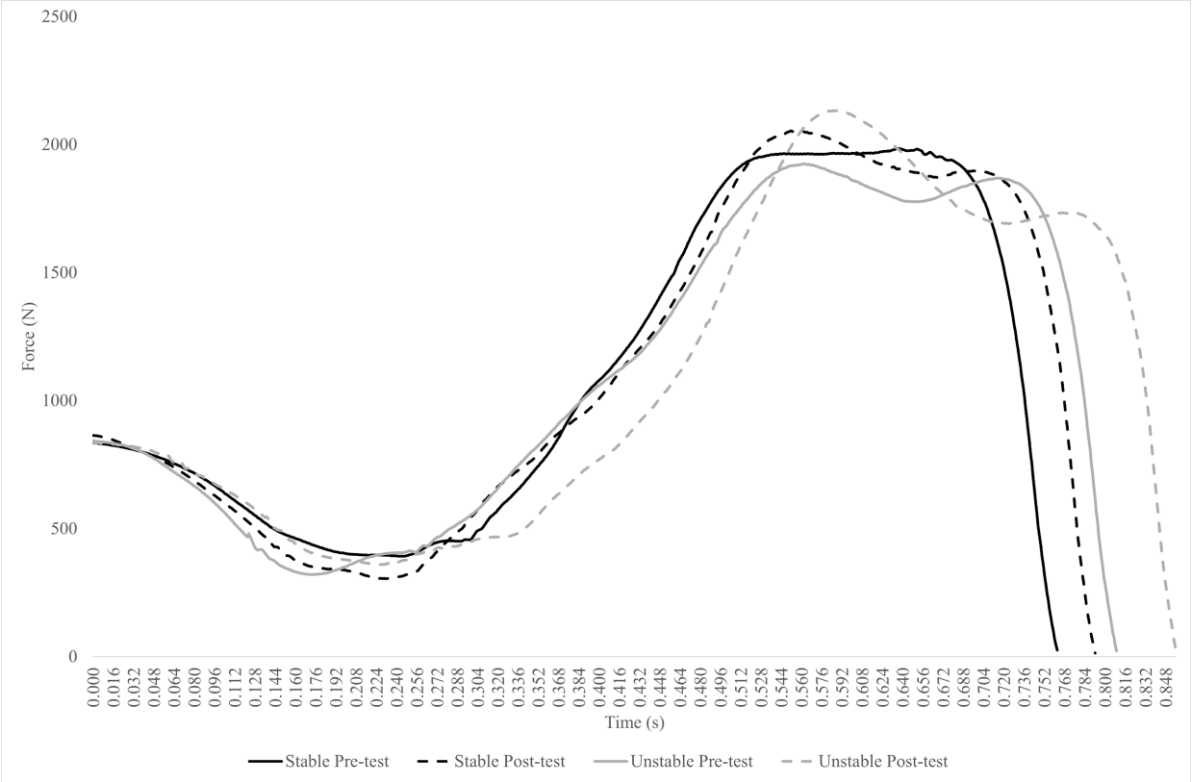


Figure 3. Force-time curves for stable and unstable loading conditions

4. DISCUSSION

The present study aimed to observe how PAPE was affected between stable and unstable loads through changes in force-time variables in the CMJ with respect to time, condition, and interaction. The results of this experiment indicated that there were significant findings with respect to time in jump height, takeoff velocity, mean braking force, braking impulse, propulsive impulse, COM depth, propulsive duration, and braking rate of force development. These outcomes demonstrate an effect on acute PAPE regardless of condition when utilizing loaded plyometrics.

Though this is the first study of its kind to investigate plyometrics with unstable loads and their effects on PAPE relative to stable loads. Our study differs from previous research conducted by Jirovska et al. (2023) who utilized stable and unstable back squats to potentiate the CMJ, resulting in no significant findings between condition or time, including jump height. Squats were programmed at 85% of the participants' one repetition maximum (1RM) for both conditions, with the unstable condition accounting for 15% of that total load. Based on previously researched training modalities, this may not have been a high enough relative threshold to warrant a different stimulus from stable loading. Previous studies have suggested that a load exceeding 20% of

the cumulative weight may be required to evoke a different adaptation versus a traditionally loaded resistance (Stevenson et al., 2010; Wallace et al., 2010). The water bag utilized in our study inherently consists of 100% unstable load and subjects in our study performed squat jumps instead of high intensity back squats. However, these differences warranted no significant outcomes between conditions.

Another component we aimed to correct in the protocol was utilizing the SAID principle by having participants perform sets of continuous squat jumps rather than a loaded squat pattern. Though squats at high intensities have shown a great effect on muscular recruitment (Corradi et al., 2021; Yoon et al., 2012), there have been mixed results on their potentiating abilities of subsequent CMJs. Some findings observed significant efficacy (Bauer et al., 2019; Weber et al., 2008) while others report no significant findings (Jones & Lees, 2003; Moir et al., 2011). In a study that compared muscle activation between the back squat and squat jump, it was observed that the squat jump provided greater muscular recruitment than the back squats at loads equal to around 60% of the participants' 1RM (Sugisaki et al., 2014). Though this load is less than what Jirovska and colleagues (2023) had programmed, it provides insight to the recruitment demands that may occur between loaded resistance exercises and plyometrics. This difference in muscular recruitment is supported by the mechanical loading continuum, which suggests that plyometric training imposes a greater mechanical stimulus than traditional resistance training (Ottinger et al., 2025). Thus, these different training modalities may have unique effects on PAPE. Additionally, Wezenbeek and colleagues (2022) utilized water bags and observed greater recruitment in stabilizer muscles in the soleus and glute medius when compared to a stable dowel. However, they did not evaluate a jump post intervention to investigate if the increased recruitment led to any kinematic changes in CMJ performance. Findings translated similarly to the upper body where Crosbie et al. (2024) investigated bar speed variance and muscle activation between stable and unstable bench presses. Greater recruitment occurred in the unstable condition but bar speed suffered as a result of the instability of the load. No testing was performed outside of the intervention, making it unclear if either intervention had an effect on any PAPE characteristics .

In this study, the braking phase of the CMJ underwent the most change from pre- to post- jump. Mean force, impulse, and rate of force development, with respect to the braking phase, all exhibited significant changes post

intervention regardless of condition. The protocol would be the likely explanation for why this may have been the case. In a continuous squat jump, the emphasis is on quickly absorbing momentum and reversing it rapidly into another jump. Out of the three jumps in each set, two of them required landing from elevation from the prior jump, presenting a greater relative intensity during the braking phase of the jump as compared to a conventional CMJ for one repetition (Wallace et al., 2010). This specific protocol may impose a greater emphasis on the braking phase of the jump compared to prior CMJ PAPE research, and may help explain our unique braking phase findings. Another consideration worth noting is that retest occurred directly after the protocol, and though it is unclear whether or not strategy is affected with time, past research has suggested that PAPE has demonstrated its greatest effect in the 3-9 minute window (Bampouras & Esformes, 2020; Bauer et al., 2019; Beato et al., 2021). Evidently, our findings did demonstrate improvements directly after intervention, sooner than that of previously reported windows of time. Though the results were not significant between conditions , it is worth noting that the unstable protocol witnessed a greater increase in jump height, on average, by 2.5cm, compared to the stable which observed a 0.6cm improvement. This may stem from the increased muscle fiber recruitment in stabilizing muscles, which was observed in the Wezenbeek et al. (2022) study that also utilized a water bag. This enhanced recruitment could allow for more force production from muscles that may not have been stimulated to the same degree from the stable condition in the barbell.

The rationale behind the selection of water bags as the medium for the unstable intervention is due to a number of reasons. For one, the usage of them is growing rapidly in a number of sports and rehabilitation settings (Verducci, 2025). While evidence does support the justification for their use in a rehabilitation setting (Wezenbeek et al., 2022), little data has been published in regard to the efficacy of their usage relating to sports performance enhancement, despite claims. Furthermore, water bag usage can be a versatile and viable option when conventional gym equipment is not readily accessible, like on a field of competition.

Limitations

A potential limitation to the experiment could have been the level of perceived resistance from participants. Other studies programmed the load off the participants' one repetition maximum, whereas in this study a constant 20.4 kg load was used in both conditions, despite varying levels of strength and

power in each participant. Additionally, only one jump was recorded after each intervention, which occurred shortly after the second set of jumps for each protocol whereas other research collected data at multiple time points post intervention.

Future research could investigate these modalities in other planes of motion, such as the frontal plane or in a more sport-specific setting through rotational sports and their effect on performance during competition. Investigation over a chronic training setting may be worth studying to determine if there is a variance in adaptive changes over a longer period of time, as participants become more acclimatized to an unstable load and how that may affect their force production.

5. PRACTICAL APPLICATIONS

With there being no data of significance between conditions, practitioners can utilize more unconventional methods to get a similar PAPE effect when conventional gym equipment is not readily available pre-competition for a trained population. Though effectiveness was demonstrated in accomplishing a similar outcome among conditions, this does not indicate that unstable loads should or can replace conventional stable loads, rather they act as a supplemental and complementary modality to them. And while in this instance, water bags are more portable and practical in a competitive environment, more data needs to be collected before performing strenuous movements that may be viewed as unorthodox.

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References

Bampouras, T. M., & Esformes, J. I. (2020). Bodyweight squats can induce post-activation performance enhancement on jumping performance: A brief report. *International Journal of Physical Education, Fitness and Sports*, *9*(4), 31–36. https://doi.org/10.34256/ijpefs2044

Bauer, P., Sansone, P., Mitter, B., Makivic, B., Seitz, L. B., & Tschan, H. (2019). Acute effects of back squats on countermovement jump performance across multiple sets of a contrast training protocol in resistance-trained males. *Journal of Strength and Conditioning Research*, *33*(4), 995–1000. https://doi.org/10.1519/JSC.0000000000002422

Beato, M., Stiff, A., & Coratella, G. (2021). Effects of postactivation potentiation after an eccentric overload bout on countermovement jump and lower-limb muscle strength. *Journal of Strength and*

Conditioning Research, 35(7), 1825–1832. https://doi.org/10.1519/JSC.0000000000003005

Blazevich, A. J., & Babault, N. (2019). Post-activation potentiation versus post-activation performance enhancement in humans: Historical perspective, underlying mechanisms, and current issues. *Frontiers in Physiology, 10*, Article 1359. https://doi.org/10.3389/fphys.2019.01359

Cardona Gómez, J. S., & Rojas Jaramillo, A. (2025). Does post-activation performance enhancement (PAPE) occur with strength exercises on unstable surfaces? Effects on jump and sprint performance in a randomized crossover trial. *Retos, 67*, 182–195. https://doi.org/10.47197/retos.v67.110599

Chavda, S., Bromley, T., Jarvis, P., Williams, S., Bishop, C., Turner, A., Lake, J., & Mundy, P. (2018). Force-time characteristics of the countermovement jump: Analyzing the curve in Excel. *Strength and Conditioning Journal, 40*(2), 67–77. https://doi.org/10.1519/SSC.0000000000000353

Corradi, E. F. F., Lanza, M. B., Lacerda, L. T., Andrushko, J. W., Martins-Costa, H. C., Diniz, R. C. R., Lima, F. V., & Chagas, M. H. (2021). Acute physiological responses with varying load or time under tension during a squat exercise: A randomized cross-over design. *Journal of Science and Medicine in Sport, 24*(2), 171–176. https://doi.org/10.1016/j.jsams.2020.07.015

Crosbie, L., Langdon, D., & Thompson, N. (2024). Effects of unstable load vs stable load on muscle activation and bar velocity during a bench press [Conference abstract]. *Graduate Journal of Sports Science, Coaching, Management, & Rehabilitation, 1*(3), 32. https://doi.org/10.19164/gjsscmr.v1i3.1514

Cuenca-Fernández, F., Smith, I. C., Jordan, M. J., MacIntosh, B. R., López-Contreras, G., Arellano, R., & Herzog, W. (2017). Nonlocalized postactivation performance enhancement (PAPE) effects in trained athletes: A pilot study. *Applied Physiology, Nutrition, and Metabolism, 42*(10), 1122–1125. https://doi.org/10.1139/apnm-2017-0217

Drinkwater, E. J., Pritchett, E. J., & Behm, D. G. (2007). Effect of instability and resistance on unintentional squat-lifting kinetics. *International Journal of Sports Physiology and Performance, 2*(4), 400–413.

Jirovska, R., Kay, A. D., Tsatalas, T., Van Enis, A., Kokkotis, C., Giakas, G., & Mina, M. A. (2023). The influence of unstable load and traditional free-weight back squat exercise on subsequent countermovement jump performance. *Journal of Functional Morphology and Kinesiology, 8*(4), Article 167. https://doi.org/10.3390/jfmk8040167

Jones, P., & Lees, A. (2003). A biomechanical analysis of the acute effects of complex training using lower limb exercises. *Journal of Strength and Conditioning Research, 17*(4), 694–700.

Lake, J. P., & McMahon, J. J. (2018). Within-subject consistency of unimodal and bimodal force application during the countermovement jump. *Sports, 6*(4), Article 143. https://doi.org/10.3390/sports6040143

Lawrence, M. A., & Carlson, L. A. (2015). Effects of an unstable load on force and muscle activation during a parallel back squat. *Journal of Strength and Conditioning Research, 29*(10), 2949–2953. https://doi.org/10.1519/JSC.0000000000000955

McMahon, J. J., Suchomel, T. J., Lake, J. P., & Comfort, P. (2018). Understanding the key phases of the countermovement jump force-time curve. *Strength and Conditioning Journal, 40*(4), 96–106. https://doi.org/10.1519/SSC.0000000000000375

Moir, G. L., Mergy, D., Witmer, C., & Davis, S. E. (2011). The acute effects of manipulating volume and load of back squats on countermovement vertical jump performance. *Journal of Strength and Conditioning Research, 25*(6), 1486–1491. https://doi.org/10.1519/JSC.0b013e3181da8597

Ottinger, C. R., Hall, K. M., Shepherd, S. A., Campbell, A. J., & Biscardi, L. M. (2025). The mechanical loading continuum and its application in strength and conditioning and rehabilitation. *Strength and Conditioning Journal, 47*(2), 205–214. https://doi.org/10.1519/SSC.0000000000000868

Owen, N. J., Watkins, J., Kilduff, L. P., Bevan, H. R., & Bennett, M. A. (2014). Development of a

criterion method to determine peak mechanical power output in a countermovement jump. *Journal of Strength and Conditioning Research, 28*(6), 1552–1558. https://doi.org/10.1519/JSC.0000000000000311

Rassier, D. E., & MacIntosh, B. R. (2000). Coexistence of potentiation and fatigue in skeletal muscle. *Brazilian Journal of Medical and Biological Research, 33*(5), 499–508.

Saeterbakken, A. H., & Fimland, M. S. (2013). Muscle force output and electromyographic activity in squats with various unstable surfaces. *Journal of Strength and Conditioning Research, 27*(1), 130–136.

Sale, D. G. (2002). Postactivation potentiation: Role in human performance. *Exercise and Sport Sciences Reviews, 30*(3), 138–143. https://doi.org/10.1097/00003677-200207000-00008

Simonelli, C., Rossi, A., Merati, G., Malagoli Lanzoni, I., & Nigro, F. (2024). Acute effects of different warm-up protocols on jump performance in elite male Italian handball players. *Applied Sciences, 14*(23), Article 11000. https://doi.org/10.3390/app142311000

Sirieiro, P., Nasser, I., Dobbs, W. C., Willardson, J. M., & Miranda, H. (2021). The effect of set configuration and load on post-activation potentiation on vertical jump in athletes. *International Journal of Exercise Science, 14*(4), 902–911. https://doi.org/10.70252/CCLW6758

Smith, J. C., & Fry, A. C. (2007). Effects of a ten-second maximum voluntary contraction on regulatory myosin light-chain phosphorylation and dynamic performance measures. *Journal of Strength and Conditioning Research, 21*(1), 73–76.

Stevenson, M. W., Warpeha, J. M., Dietz, C. C., Giveans, R. M., & Erdman, A. G. (2010). Acute effects of elastic bands during the free-weight barbell back squat exercise on velocity, power, and force production. *Journal of Strength and Conditioning Research, 24*(11), 2944–2954.

Sugisaki, N., Kurokawa, S., Okada, J., & Kanehisa, H. (2014). Difference in the recruitment of hip and knee muscles between back squat and plyometric squat jump. *PLoS ONE, 9*(6), Article e101203. https://doi.org/10.1371/journal.pone.0101203

Sweeney, H. L., Bowman, B. F., & Stull, J. T. (1993). Myosin light chain phosphorylation in vertebrate striated muscle: Regulation and function. *American Journal of Physiology–Cell Physiology, 264*(5), C1085–C1095. https://doi.org/10.1152/ajpcell.1993.264.5.C1085

Verducci, T. (2025, April 29). Paul Skenes is aiming to break baseball's ultimate barrier. *Sports Illustrated*. https://www.si.com/mlb/paul-skenes-rise-of-pitching-velocity-baseball-ultimate-barrier-digital-cover

Wallace, B. J., Kernozek, T. W., White, J. M., Kline, D. E., Wright, G. A., Peng, H.-T., & Huang, C.-F. (2010). Quantification of vertical ground reaction forces of popular bilateral plyometric exercises. *Journal of Strength and Conditioning Research, 24*(1), 207–212. https://doi.org/10.1519/JSC.0b013e3181c3b841

Weber, K. R., Brown, L. E., Coburn, J. W., & Zinder, S. M. (2008). Acute effects of heavy-load squats on consecutive squat jump performance. *Journal of Strength and Conditioning Research, 22*(3), 726–730. https://doi.org/10.1519/JSC.0b013e3181660899

Wezenbeek, E., Verhaeghe, L., Laveyne, K., Ravelingien, L., Witvrouw, E., & Schuermans, J. (2022). The effect of aquabag use on muscle activation in functional strength training. *Journal of Sport Rehabilitation, 31*(4), 420–427. https://doi.org/10.1123/jsr.2021-0245

Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M. C., Jo, E., Lowery, R. P., & Ugrinowitsch, C. (2013). Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. *Journal of Strength and Conditioning Research, 27*(3), 854–859.

Yoon, J., Shiekhzadeh, A., & Nordin, M. (2012). The effect of load weight vs. pace on muscle recruitment during lifting. *Applied Ergonomics, 43*(6), 1044–1050.