

Acute effects of light weighted vests on sprint velocity, step frequency, and step length in female basketball players

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Abstract:

Sprint acceleration is a critical performance factor in basketball, and weighted vests (WVs) offer a practical means of resisted sprint training. However, limited female-specific evidence exists on the acute effects of light wearable loads on acceleration-phase sprint velocity and its kinematic determinants. This study examined the acute effects of light WVs on sprint velocity and step kinematics in female basketball players, with an emphasis on individual adjustment strategies. Twelve collegiate athletes completed two 20-m linear sprints under three randomized conditions: no load (0%), WV at 3% body mass, and WV at 5% body mass. Sprint performance was assessed using timing gates, and a side-on high-speed camera (240 fps) recorded the 5–15 m interval to quantify step frequency (SF), step length (SL), ground contact time (GCT), and flight time over one gait cycle. Sprint velocity was computed as $SF \times SL$. Group comparisons using one-way ANOVA revealed a significant main effect only for sprint velocity ($F(2,22) = 3.78$, $p < 0.05$, $\omega^2 = 0.13$), with velocity at 5% significantly lower than at 0% ($p < 0.05$). By contrast, SF, SL, GCT, and flight time did not differ significantly across conditions at the group level. However, within-subject percent-change analyses provided clearer mechanistic insight. At 5% load, the percent change in SF was strongly and positively associated with the percent change in sprint velocity ($r = 0.871$, $p < 0.001$), whereas percent changes in SF and SL were negatively related ($r = -0.725$, $p < 0.01$), indicating a systematic SF–SL tradeoff under load. Athletes who best preserved sprint velocity at 5% tended to maintain cadence (SF) while accepting modest reductions in SL; conversely, larger velocity decrements coincided with reduced SF despite relatively maintained SL. The unloaded pitch–stride ratio (PS ratio = SF/SL) showed a moderate correlation with the direction of SL adjustment at 5% ($r = 0.583$, $p < 0.05$), suggesting that baseline running style may relate to how athletes redistribute SF and SL when loaded, although this relationship does not support predictive use. Practically, initiating WV exposure at approximately 3% body mass while prioritizing cadence preservation and monitoring velocity decrement may be advisable for female basketball players. Overall, under light loading, sprint-velocity maintenance appears to hinge on protecting SF, highlighting the need for individualized WV prescription and monitoring.

Keywords: wearable resistance; acceleration phase; spatiotemporal parameters; cadence regulation; ground contact time; individual variability

Introduction

Sprint ability is a key determinant of performance in many sports and is particularly important in team sports characterized by repeated high-intensity actions (Sweeting et al., 2017). In basketball, players frequently perform short sprints interspersed with rapid decelerations and changes of direction; therefore, the ability to accelerate quickly is more relevant than sustaining maximal speed over longer distances (Scanlan et al., 2012; Stojanović et al., 2018). From an applied perspective, training interventions that improve acceleration while preserving movement quality and remaining feasible in the field are desirable in basketball settings.

Resisted sprint training is a widely used approach to enhance acceleration by increasing external demand and promoting adaptations in force production and sprint-specific mechanics (Cronin & Hansen, 2006; Young et al., 2001). Common resisted modalities include sled towing and wearable resistance strategies, each with distinct practical and mechanical characteristics (Petrakos et al., 2016; Bertochi et al., 2024). Among wearable approaches, weighted vests (WVs) are appealing because they require minimal equipment, can be implemented rapidly, and integrate easily into routine sprint drills. Systematic reviews indicate that wearable resistance can acutely alter sprint kinematics and may support performance improvements when appropriate loading and progression are applied (Bertochi et al., 2024). Importantly, acute responses are not merely undesirable decrements; they can provide useful information about the stimulus imposed by the load and the athlete's strategy for coping with it, thereby informing load selection and individualized prescription.

However, evidence on WVs remains dominated by male cohorts, and female-specific data are limited (Simpson et al., 2020; Bertochi et al., 2024). This is relevant because sex-based physiological and biomechanical characteristics may influence responses to external loading. Women often exhibit lower rates of force development and lower musculotendinous stiffness than men, which may affect contact mechanics and the

ability to maintain step frequency under load (Karlsson & Jacobs, 1981; Granata & Wilson, 2002; Kubo et al., 2003; Hunter, 2014). Moreover, sprinting is a whole-body task in which upper-limb and trunk coordination can influence running mechanics, and sex-related differences in sprint mechanics have been reported, including differences in the influence of arm swing on ground reaction forces and trunk movements (Hiruma & Kariyama, 2023). Determinants of sprint performance and the relative contributions of kinematic variables may also differ between sexes (Gleadhill & Nagahara, 2021), cautioning against directly generalizing male-dominant findings to female athletes. Consequently, practitioners currently have limited evidence to guide WV load selection and technique monitoring specifically for female basketball players, despite the increasing practical use of WVs in the field.

Sprint velocity is determined by the product of step frequency (SF) and step length (SL) (Hay, 1993), which commonly display a tradeoff (Hunter et al., 2004). Reviews often report that external loading reduces sprint velocity and is frequently accompanied by shorter SL and longer ground contact time (GCT), suggesting a strategy of longer stance to generate impulse (Petrakos et al., 2016; Bertochi et al., 2024). Nevertheless, these patterns may depend on load magnitude, sprint phase, and athlete population, and group mean changes may obscure meaningful inter-individual adjustment strategies. Because basketball sprints are typically performed in the acceleration phase, examining responses within a mid-acceleration window (e.g., 5–15 m) may provide practical insight relevant to training and monitoring, particularly when light loads are used to preserve sprint technique. Additionally, sprint technique characteristics in elite sprinters, such as arm swing direction during sprint running, have been described (Hiruma & Kariyama, 2022), underscoring the potential importance of coordinated whole-body movement patterns when interpreting sprint responses to external loads.

Therefore, the purpose of this study was to determine the acute influence of light WV loading (3% and 5% of body mass) on sprint velocity and its kinematic determinants (SF and SL) in female collegiate basketball players, focusing on the 5–15 m segment of a 20-m sprint. In addition to between-condition comparisons, within-subject percent-change analyses were used to examine the relation between individual changes in SF and SL and changes in sprint velocity, and we explored whether the unloaded pitch-stride ratio (PS ratio = SF/SL) is associated with the direction of SL adjustment under the 5% load (Naito et al., 2015).

Material & methods

Participants

Twelve female collegiate basketball players participated (age: 19.8 ± 0.6 years; height: 164.2 ± 5.1 cm; body mass: 59.4 ± 4.8 kg). None reported lower-limb injury within the previous six months. All participants received a full explanation of the study and provided written informed consent. The protocol was approved by the institutional ethics committee (Approval No.: 2025014). Data are presented as mean $\pm$ SD unless otherwise specified.

Experimental Trials

Each participant performed two 20-m linear sprints under three conditions: no load (0%), WV at 3% body mass (3%), and WV at 5% body mass (5%). The order of conditions was randomized within subjects to minimize order effects. A 5-min passive rest period separated trials, and the absence of pain or undue fatigue was confirmed before proceeding. Sprint times were recorded using photocell timing gates placed at the start and finish (TCi system; Brower Timing Systems, Draper, UT, USA). For analysis, the faster of the two trials in each condition was retained.

Video Acquisition

A high-speed digital camera (240 fps) captured side-on panning footage from a position approximately 30 m lateral to the sprint path. The analysis corridor spanned 5–15 m from the start line. Four calibration markers were placed at 1-m intervals within the field of view.

Kinematic Analysis

One full gait cycle (from left foot contact to the subsequent left foot contact) was digitized for the left toe and the four calibration markers using a motion-analysis system (Frame-DIAS V, Q'sfix Co., Japan). After spatial calibration, trajectories were low-pass filtered at 2–8 Hz. Sprint velocity was computed as $SF \times SL$. SF was defined as the inverse of half the cycle time ($\text{steps} \cdot \text{s}^{-1}$). SL was defined as half the horizontal displacement of the left toe over the cycle ($\text{m} \cdot \text{step}^{-1}$). GCT and flight time were derived from foot-strike and toe-off events. Following Naito et al. (2015), the PS ratio was calculated as SF/SL in the no-load condition.

For all variables except the PS ratio, percent change relative to the no-load condition was computed for the 3% and 5% loads as

$$\% \Delta = (\text{value}_{\text{load}} - \text{value}_{\text{no_load}}) / \text{value}_{\text{no_load}} \times 100$$

Statistical Analysis

One-way ANOVA was used to test for differences among the three load conditions. When a significant F-value was detected, Bonferroni-adjusted pairwise comparisons were performed. Pearson product-moment correlations (after confirming normality) were used to examine associations among variables. Statistical significance was set at $\alpha = 0.05$. Effect size for ANOVA (ω^2) is reported.

Results

Mean sprint velocity, SF, and SL for the 0%, 3%, and 5% conditions are shown in Figures 1–3. One-way ANOVA revealed a significant main effect only for sprint velocity ($F(2,22) = 3.78$, $p < 0.05$, $\omega^2 = 0.13$). Post-hoc testing indicated that sprint velocity at 5% was significantly lower than at 0% ($p < 0.05$). No significant between-condition differences were found for GCT or flight time (not shown). For percent changes (5% vs. 0%), $\% \Delta \text{SF}$ was positively correlated with $\% \Delta \text{velocity}$ ($r = 0.871$, $p < 0.001$) and negatively correlated with $\% \Delta \text{SL}$ ($r = -0.725$, $p < 0.01$) (Table 1). The no-load PS ratio was positively correlated with $\% \Delta \text{SL}$ at 5% ($r = 0.583$, $p < 0.05$) (Table 2). Figure 4 presents the $\% \Delta \text{SF}$ (x-axis) and $\% \Delta \text{SL}$ (y-axis) scatter plot at 5% relative to 0%. Athletes with the smallest velocity decrements (black circles) tended to maintain SF with larger reductions in SL, whereas those with the largest velocity decrements (white circles) showed greater losses in SF with smaller reductions in SL.

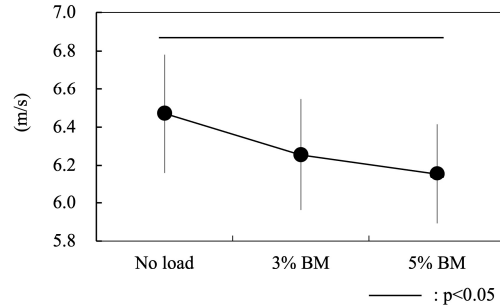


Figure 1. Sprint velocity across weighted-vest conditions (0%, 3%, and 5% body mass; mean $\pm$ SD).

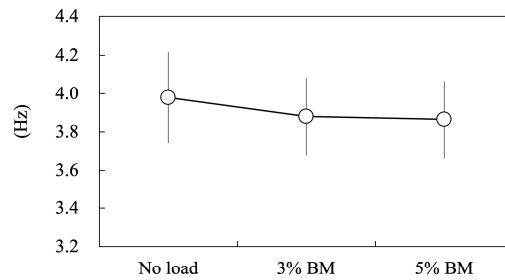


Figure 2. Step frequency across weighted-vest conditions (0%, 3%, and 5% body mass; mean $\pm$ SD).

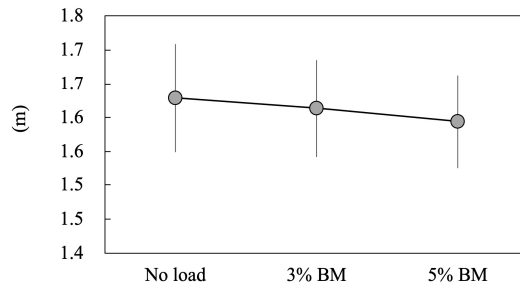


Figure 3. Mean step length across weighted-vest conditions (0%, 3%, and 5% body mass; mean $\pm$ SD)

Table 1. Correlation matrix of participant-level percent changes (5% vs 0%) in sprint variables.

Variables	1)	2)	3)	4)	5)
1) $\Delta \text{Velocity}$ (%)	—				
2) $\Delta \text{Step frequency}$ (%)	0.871 ***	—			
3) $\Delta \text{Stride length}$ (%)	-0.293	-0.725 **	—		
4) $\Delta \text{Flight time}$ (%)	0.114	0.186	-0.196	—	
5) $\Delta \text{Ground contact time}$ (%)	-0.400	-0.331	0.079	0.014	—

***: $p < 0.001$, **: $p < 0.01$

Table 2. Correlations between the no-load pitch–stride ratio (PS ratio = SF/SL) and participant-level percent changes at 5% load.

	Δ Velocity (%)	Δ Step frequency (%)	Δ Stride length (%)
SF/SL ratio	-0.069	-0.359	0.583 *

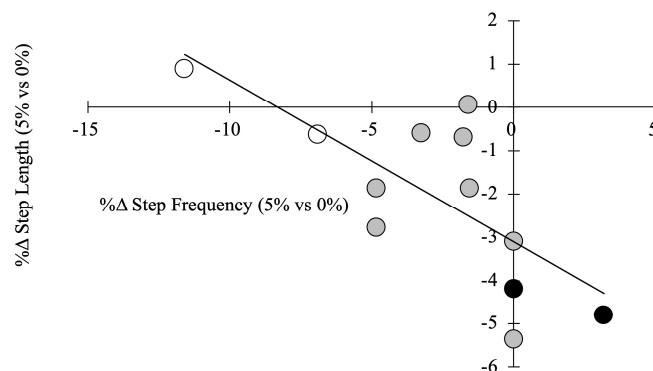
*: $p < 0.05$ 

Figure 4. Percent-change relationship between step frequency and step length at 5% load (relative to 0%).

Axes: x-axis, % Δ step frequency (5% vs 0%); y-axis, % Δ step length (5% vs 0%).

Markers: black circles (●) indicate the two athletes with the smallest velocity decrement at 5%;

white circles (○) indicate the two athletes with the largest decrement.

Discussion

This study investigated the acute effects of light external loading via weighted vests (3% and 5% body mass) on sprint mechanics in female basketball players. At the group level, only the 5% condition significantly reduced sprint velocity ($\omega^2 = 0.13$) and SF, SL, GCT, and flight time remained statistically unchanged. By contrast, within-subject percent-change analyses revealed a clear pattern: velocity changes strongly mirrored changes in SF and SF was inversely related to SL. Athletes who maintained velocity under 5% load typically preserved cadence while allowing modest SL reductions, whereas those with greater velocity losses maintained SL but exhibited cadence decrements.

These results refine current understanding of resisted sprinting. Prior crossover studies and meta-analyses consistently report that external loading acutely increases GCT, reduces SL, and slows sprint performance (Alcaraz et al., 2008; Petrakos et al., 2016; Bertochi et al., 2024), suggesting that prolonged contact is a common strategy to generate greater step impulse. However, in this female cohort under a light load and mid-acceleration assessment window, GCT did not change significantly and velocity preservation was chiefly associated with maintaining cadence. Given the determinant structure of sprint velocity (Hay, 1993) and the well-documented tradeoff between SL and SF (Hunter et al., 2004), prioritizing cadence with small SL concessions appears mechanically sensible when external load is light. This interpretation aligns with findings highlighting the importance of horizontal force application and efficiency—often expressed as the ratio of forces (RF)—during acceleration (Morin et al., 2011; Morin et al., 2012), rather than relying on prolonged contact.

Sex-specific neuromuscular characteristics likely contribute to this pattern. Women typically exhibit lower rate of force development and musculotendinous stiffness than men (Karlsson & Jacobs, 1981; Granata & Wilson, 2002; Kubo et al., 2003; Hunter, 2014), and the relative contributions of SF and SL to acceleration and maximal velocity differ by sex (Gleadhill & Nagahara, 2021). Under such constraints, distributing horizontal impulse across more frequent, efficient contacts—maintaining cadence while allowing modest SL reductions—may be a lower-risk strategy than producing larger per-step impulses via prolonged contact. This may explain why a cadence-preserving strategy emerged under light loading while studies on heavier loads or different resisted modes in male/mixed cohorts emphasize SL decrements and GCT increases (Alcaraz et al., 2008; Petrakos et al., 2016; Bertochi et al., 2024). Methodological differences—including sample characteristics (female, team-sport athletes), load intensity (light, 5%), evaluation window (mid-acceleration), and focus on individual change relationships—likely further explain discrepancies with prior summaries.

Beyond group-level means, the substantial variability and structured correlations observed here are practically relevant. Although group averages suggested minimal kinematic changes, within-subject analyses revealed performance-critical adaptations, emphasizing the value of monitoring individual SF and SL responses during WV training. Practically, cadence-focused coaching cues (e.g., rhythm prompts such as “quick off the ground”) may help athletes avoid SF decrements, and small SL reductions can be accepted to maintain velocity at light loads. These insights align with conservative progression principles, such as starting with approximately 3% body mass, monitoring velocity decrement (Vdec), and maintaining technical quality when Vdec approaches approximately 10% (Petrakos et al., 2016). The unloaded PS ratio was moderately correlated with SL

adjustments under load (Naito et al., 2015), supporting its use as a descriptive marker of running style tendencies (Haugen et al., 2019; Hunter et al., 2004). However, this relationship is correlational and does not imply predictive validity. A predictive tool would require rigorous model development, internal and external validation, and reporting of discrimination and calibration before use (Collins et al., 2015; Moons et al., 2015).

Conclusions

This study evaluated the acute effects of light weighted-vest loading (3% and 5% of body mass) on sprint velocity and step kinematics during a 20-m sprint in female collegiate basketball players, with analysis focused on the 5–15 m mid-acceleration segment. At the group level, only the 5% condition produced a statistically significant reduction in sprint velocity compared with no load, whereas mean step frequency, step length, ground contact time, and flight time did not differ significantly across the three conditions. These findings indicate that, in this cohort and sprint phase, a 5% body-mass vest is sufficient to slow sprinting and average step-level kinematics may appear relatively stable when summarized at the group mean level.

Mechanistic insight was clarified by within-subject percent-change analyses. Individual changes in sprint velocity under the 5% load were strongly and positively related to changes in step frequency, and step frequency changes were inversely related to step length changes, demonstrating a structured SF–SL tradeoff under loading. Athletes who best maintained sprint velocity tended to preserve cadence while accepting modest reductions in stride length, whereas larger velocity decrements were typically accompanied by cadence loss despite relatively equal stride length. Collectively, these results suggest that under light weighted-vest loading in female basketball players, sprint-velocity maintenance hinges on protecting step frequency, and athletes adopt diverse coordination strategies to manage the imposed load.

From an applied standpoint, the present findings support individualized weighted-vest prescription rather than reliance on group averages alone. For initial exposure, starting around approximately 3% body mass may be prudent, and progression toward 5% should be accompanied by monitoring of velocity decrement and by coaching strategies that prioritize cadence preservation. The unloaded PS ratio was moderately associated with the direction of stride-length adjustment at 5%, suggesting that baseline step-type tendencies may provide descriptive context for how athletes redistribute step frequency and step length under load; however, this association does not justify predictive use without further model development and validation. Future studies should examine a broader range of loads, sprint phases, and competitive levels, and incorporate kinetic measures (e.g., force–time characteristics) to better explain why some athletes can preserve cadence under load while others cannot.

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References

- Alcaraz, P. E., Palao, J. M., & Elvira, J. L. L. (2008). Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *J Strength Cond Res*, 22(3), 890–897. <https://doi.org/10.1519/JSC.0b013e31816611ea>
- Bertochi, G. F. A., Tasinafo Junior, M. F., Santos, I. A., Sasaki, J. E., Mota, G. R., Jordão, G. G., & Puggina, E. F. (2024). The use of wearable resistance and weighted vest for sprint performance and kinematics: A systematic review and meta-analysis. *Sci Rep*, 14, 54282. <https://doi.org/10.1038/s41598-024-54282-8>
- Collins, G. S., Reitsma, J. B., Altman, D. G., & Moons, K. G. M. (2015). Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): The TRIPOD statement. *BMJ*, 350, g7594. <https://doi.org/10.1136/bmj.g7594>
- Cronin, J. B., & Hansen, K. T. (2006). Resisted sprint training for the acceleration phase of sprinting. *Strength Cond. J*, 28(4), 42–51.
- Economou, T., Stavridis, I., Zisi, M., Fragkouli, E., Olanemi-Agilara, G., & Paradisis, G. (2021). Sprint mechanical and kinematic characteristics of national female track and field champions and lower-level competitors. *J Phys Educ Sport*, 21(Suppl. 6), 3227–3235. <https://doi.org/10.7752/jpes.2021.s6441>
- Gleadhill, S., & Nagahara, R. (2021). Kinetic and kinematic determinants of female sprint performance. *J Sports Sci*, 39(6), 609–617. <https://doi.org/10.1080/02640414.2020.1837449>

- Granata, K. P., & Wilson, S. E. (2002). Gender differences in active musculoskeletal stiffness. Part I. Quantification in controlled measurements of knee joint dynamics. *J Electromyogr Kinesiol*, 12(2), 119–126. [https://doi.org/10.1016/S1050-6411\(02\)00002-0](https://doi.org/10.1016/S1050-6411(02)00002-0)
- Hay, J. G. (1993). *The biomechanics of sports techniques* (4th ed.). Englewood Cliffs (NJ): Prentice Hall.
- Haugen, T. A., Breitschädel, F., & Seiler, S. (2019). Sprint mechanical variables in elite athletes: Are force-velocity profiles sport specific or individual? *PLoS One*, 14(7), e0215551. <https://doi.org/10.1371/journal.pone.0215551>
- Hiruma, K., & Kariyama, Y. (2023). Sex differences regarding the effects of arm swing on ground reaction force and trunk movements between track and field athletes: Focusing on the difference in the direction of arm swing. *Sci J Sport Perform*, 2(4), 553–563. <https://doi.org/10.55860/XNCN8361>
- Hiruma, K., & Kariyama, Y. (2022). Direction of arm swing of world top-class sprinters in sprint running. *J Phys. Educ Sport*, 22(5), 1155–1160. <https://doi.org/10.7752/jpes.2022.05145>
- Hunter, J. P., Marshall, R. N., & McNair, P. J. (2004). Interaction of step length and step rate in sprint running. *Med. Sci Sports Exerc*, 36(2), 261–271. <https://doi.org/10.1249/01.MSS.0000113664.15777.53>
- Hunter, S. K. (2014). Sex differences in human fatigability: Mechanisms and insight to physiological responses. *Acta. Physiol (Oxf)*, 210(4), 768–789. <https://doi.org/10.1111/apha.12234>
- Karlsson, J., & Jacobs, I. (1981). Is the significance of muscle fiber types to muscle metabolism different in females. than in males? In J. Borms, M. Hebbelinck, & A. Venerando (Eds.), *Women and sport* (pp. xx–xx). New York: Karger.
- Kubo, K., Kanehisa, H., Kawakami, Y., & Fukunaga, T. (2003). Gender differences in the viscoelastic properties of tendon structures. *Eur J Appl Physiol*, 88(6), 520–526. <https://doi.org/10.1007/s00421-002-0744-8>
- Moons, K. G. M., Altman, D. G., Reitsma, J. B., et al. (2015). Transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD): Explanation and elaboration. *Ann Intern Med*, 162(1), W1–W73. <https://doi.org/10.7326/M14-0698>
- Morin, J.B., Bourdin, M., Edouard, P., Peyrot, N., Samozino, P., & Lacour, J.R. (2012). Mechanical determinants of 100-m sprint running performance. *Eur J Appl Physiol*, 112(11), 3921–3930. <https://doi.org/10.1007/s00421-012-2379-8>
- Morin, J.B., Edouard, P., & Samozino, P. (2011). Technical ability of force application as a determinant factor of sprint performance. *Med Sci Sports Exerc*, 43(9), 1680–1688. <https://doi.org/10.1249/MSS.0b013e318216ea37>
- Naito, H., Kariyama, Y., Yamamoto, K., & Tanigawa, S. (2015). Sprint step-type specific characteristics of anthropometric and kinematic variables in sprinting acceleration. *Proc 33rd Congr Int Soc Biomech Sports*, 338–341.
- Petrakos, G., Morin, J.-B., & Egan, B. (2016). Resisted sled sprint training to improve sprint performance: A systematic review. *Sports Med*, 46(3), 381–400. <https://doi.org/10.1007/s40279-015-0422-8>
- Scanlan, A. T., Dascombe, B. J., Reaburn, P. R., & Dalbo, V. J. (2012). The physiological and activity demands experienced by Australian female basketball players during competition. *J Sci Med Sport*, 15(4), 341–347. <https://doi.org/10.1016/j.jsams.2011.12.008>
- Simpson, J., Cosio-Lima, L., Scudamore, E. M., O’Neal, E. K., et al. (2020). Effects of weighted-vest loading during daily living activities on countermovement jump and sprint performance. *Int J Sports Physiol Perform*. <https://doi.org/10.1123/ijsspp.2019-0318>
- Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: A systematic review. *Sports Med*, 48(1), 111–135. <https://doi.org/10.1007/s40279-017-0794-z>
- Sweeting, A. J., Cormack, S. J., Morgan, S., & Aughey, R. J. (2017). When is a sprint a sprint? A review of the analysis of team-sport athlete activity profile. *Front Physiol*, 8, 432. <https://doi.org/10.3389/fphys.2017.00432>
- Young, W. B., Benton, D., Duthie, G., & Pryor, J. (2001). Resistance training for short sprints and maximum-speed sprints. *Strength Cond J*, 23(2), 7–13.