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Effects of Optimum Power Load vs Mixed Model Training Methods on Lower Limb Strength and Dynamic Performance in Female Athletes

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ABSTRACT

Training with optimum power load (OPL) was shown to result in improved lower limb strength. However, recent study has recommended using the mixed model training (MMT) method which involves frequent varying of training loads. As the training adaptations to OPL and MMT training methods have not been directly compared, hence, the purpose of this study was to compare the effects of OPL and MMT on lower limb neuromuscular adaptations. Seventeen female athletes (age: 22±2.9 years, height: 162.7±5.2 cm, bodyweight: 60.5±9.6 kg) were randomly assigned to either MMT or OPL training (OPLT) group. Both groups performed similar training program twice a week for six weeks. However, MMT performed the loaded CMJ exercise at -15-20% and +20-25% of OPL, while OPLT performed it at OPL. Pre- and post-test included CMJ, 5-0-5 change of direction test (505 COD), 20-m sprint and isometric mid-thigh pull (IMTP). Both groups showed significant improvement in CMJ height (MMT: P=0.025, g=0.48, OPLT: P=0.003, g=0.72), 505 COD (MMT: P<0.001, g=1.12, OPLT: P=0.006, g=0.36), 20-m sprint (MMT: P<0.001, g=0.65, OPLT: P=0.002, g=0.28), IMTP peak force (MMT: P<0.001, g=0.66, OPLT: P<0.001, g=0.46) and IMTP force at 100 ms (MMT: P=0.019, g=0.66, OPLT: P=0.001, g=0.60). Only MMT significantly improved CMJ mean propulsion force (P=0.004, g=0.34), a variable that contributes to greater jump height. While OPLT resulted in greater effect for CMJ height, MMT resulted in greater effect for 505 COD, 20-m sprint and IMTP performance. These findings suggest that frequent varying of resistance may induce greater neuromuscular adaptations.

Keywords: Countermovement jump, change of direction, sprint, isometric mid-thigh pull.

INTRODUCTION

Optimal power load (OPL) training has been gaining interest as an effective form of power training in recent years (Cormie et al., 2011, Loturco et al., 2015; Loturco et al., 2016; Loturco et al., 2020, Loturco et al., 2021). The maximum power output that can be achieved during a particular exercise is referred to as the OPL (Cormie et al., 2011), and can be determined using a straightforward incremental testing procedure that relies on system power, which is calculated as a relative percentage of body mass. It can also be determined via bar-power (bar-force, bar-velocity) (Loturco et al., 2022). It is believed that bar-power tends to reach its peak at moderate loads, typically ranging from 30% to 60% of the one-repetition maximum (1RM). Intervention studies investigating the effects of training with OPL have reported its beneficial effects on lower limb strength and power performance (Loturco et al., 2015; Loturco et al., 2016). However, these studies were conducted on male athletes, hence, the effectiveness of OPL training in female remains understudied. It is, therefore, important to investigate the effects of OPL training on female athletes to provide practitioners with more information to better plan the training programs for this population.

Mixed model training (MMT) is another training approach that has been reported to improve power by developing both the force and velocity factors, resulting in more comprehensive adaptation throughout the force-velocity continuum (Haff et al., 2012, Hernandez-Davo & Sabido, 2022; Toji et al., 2004). Being able to employ multiple loads simultaneously to maximize both force and velocity is important in meeting the specific demands of certain sports. Due to the nature of team and intermittent sports, power production at a range of intensities is required depending on the dynamics and proceedings of a match (Harper et al., 2022; Taylor et al., 2017). Hence, regularly varying the training stimuli is a crucial factor in achieving simultaneous improvements in strength and jumping performance (Hernandez-Davo & Sabido, 2023). This was evident in the study by Hernandez-Davo & Sabido (2023) who showed that varying the resistance stimuli frequently within a training session improved strength and jump performance more than infrequent changing of the load. The increase in muscular strength can be attributed to the influence of load variability on the neuromuscular system, as observed in a study by Monteiro et al. (2009). This finding aligns with the results of a meta-analysis that demonstrated that complex training approaches yielded greater improvements in maximal strength compared to non-variable techniques in athletes (Bauer et al., 2019)

The findings on MMT suggest that performing loaded plyometric exercise using MMT may result in greater enhancement in neuromuscular performance than OPL. Given that there is still a lack of research comparing the two training methods, understanding the differential effects of these training methods may help practitioners better design programs. In addition, as female s may exhibit distinct responses to various training interventions in due to their unique physiological and morphological characteristics (Costello et al., 2014), it is important to conduct more training intervention studies in this population to better inform practitioners working with female athletes. For example, female may increase relative strength more than male (Nuzzo, 2023), and have greater increase and decrease in the percentage of type I and type IIx muscle fiber, respectively, after a period of strength training (Martel et al., 2006). Hence, the purpose of this study was to compare the effects of OPL and MMT on lower limb neuromuscular adaptations in female athletes. It was hypothesized that MMT would result in greater adaptations.

METHODS

Experimental Approach to the Problem

This study used a randomized between-subject design involving two groups of participants lasting six weeks with two training days per week. Participants were required to attend one familiarization session, two pre- and post-tests sessions, and 12 training sessions over six weeks. During the familiarization session, participants were briefed on the training program and were familiarized with the range of tests including the countermovement jump (CMJ), loaded CMJ, 5-0-5 change of direction (505 COD), 20-m sprint and the isometric mid-thigh pull (IMTP) test. These tests were conducted during the first pre- and post-test in the stated order. During the second pre-test, participants performed the loaded CMJ test to determine their OPL. Each testing session was separated by 48 h. The post-test session was conducted five days after the final training session. All testing and training sessions were preceded by a standardized warm up that consisted of a 5-min treadmill jog at self-selected pace followed by 10 repetitions each of bodyweight squat, hip hinge and calf raise exercises, and five repetitions of submaximal CMJ. Participants were randomly assigned to the MMT or OPLT group using a web-based randomization tool. (https://wheelofnames.com/).

Participants

The physical characteristics of the participants are displayed in Table 1. A convenient sample of 20 well-trained female softball players from the Singapore national training squad were recruited for this study. Three athletes (n = MMT: 1, OPLT: 2) dropped out from the study due to injury unrelated to the study. Inclusion criteria for the study included: 1) female with at least one year of resistance training experience; 2) age between 18 to 35 years old; 3) not sustaining any musculoskeletal injury within

Table 1. Physical characteristics of participants (n= 17).

	All (n= 17)	MMT (n= 9)	OPLT (n= 8)
Age (year)	22 ± 2.87	21.78 ± 2.49	22.25 ± 3.41
Height (cm)	162.69 ± 5.19	163.09 ± 4.94	162.24 ± 5.78
Bodyweight (kg)	60.52 ± 9.62	57.27 ± 5.75	64.18 ± 12.04

three months prior to participation. All participants provided written consent prior to participation. Parental consent was sought for participants below the age of 21 years old. The study commenced after obtaining ethical approval from the Nanyang Technological University Institutional Review Board (NTU- IRB-2022-490). The study took place at the start of the pre-season training period where athletes just returned to training after a one-month break.

Procedure

Countermovement jump

The CMJ was performed on dual force plates (Force Decks, VALD Performance, FD4000, Queensland, Australia) sampling at 1000 Hz. During the CMJ, participants were asked to keep their arms akimbo to eliminate arm swing and maintain their back upright to reduce angular displacement of the hips. Participants performed 3 jumps, separated by 30 s rest intervals. The commercially available ForceDecks software (VALD Performance, ForceDecks, Queensland, Australia) was used to analyse and generate the CMJ variables. Take-off was defined as the time point at which the total vertical force fell below the threshold of 20 N (Heishman et al., 2019). Dependent variables included jump height, time to take-off (TTO) and concentric mean propulsion force (MPF). The average values of all three trials were recorded and analysed.

5-0-5 Change of direction

The test followed the procedure described by Gabbett et al. (2008). Participants started in a standing position with their preferred foot behind the starting line, followed by a forward acceleration to reaching the 10 m mark at maximal intent. Upon running past the first set of timing gates (Swift Speedlight, Wacol, Australia), timing for the test started. Upon reaching the 5-m mark, the athlete attempted a 180° turn and re-accelerated at maximal intent till she finished the second 5 m distance. The average time (s) obtained from 2 attempts were taken in for further analysis. Figure 2 illustrates the set-up of the 505COD test.

20-m sprint

The 20-m sprint was administered as a test of sprint ability. All subjects performed three trials separated by a 2 min recovery period. Timing gates (Swift Speedlight, Wacol, Australia) were set up at 0-, 5-, 10- and 20-m. Subjects will start 0.2 m from the light gate to prevent any early triggering of the initial start gate, with a two-point staggered start. The average time obtained from the 3 trials were used for further analysis. Within session reliability data for all sprint measures were ICC = 0.89 – 0.97, CV% = 0.8 – 2.4.

Isometric mid-thigh pull

The IMTP was performed on the same dual force plates. Subjects were asked to adopt a posture that reflects the start of the second pull of the clean resulting in a knee flexion angle of 125-145o, and hip flexion angle of 140-150o stance (Comfort et al., 2019). A handheld goniometer was used to ensure that subjects adopt the required knee and hip angles. Subjects were required to hold on to the bar with elbows fully extended. Upon the tester's command, subjects were instructed to pull the bar, by driving their feet into the floor, 'as fast and as hard possible'. Subjects maintained the tension for a period of 5 s. Subjects performed the IMTP twice, as long as the PF is within 250 N between trials. Each attempt was separated by a 2 min recovery period (Comfort et al., 2019). The average of the peak force generated by the two trials were recorded and analysed. In addition, force at 100ms (Force100) from the onset of pull were determined for each trial. The onset of pull was determined based on an increase of >5 standard deviation (SD) of participants body mass during a period of quiet standing prior to the pull (Dos' Santos et al., 2017)

Loaded countermovement jump

The loaded CMJ was performed with a 8 or 10 kg barbell so that the first set was performed at 20% of participants' bodyweight. Participants were instructed to execute 3 repetitions of the CMJ at maximal power against increasing loads. A 10% increase in load was gradually added in each successive set until a decrease in peak power (PP) was observed. A 3 min rest interval was provided

Table 2. Intervention training program.

Session 1	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Loaded CMJ	4 x 5	4 x 5	4 x 5	4 x 5	4 x 5	2 x 5
Walking Lunge	3 x 8 ea	3 x 8 ea	3 x 8 ea	3 x 6 ea	3 x 6 ea	2 x 6 ea
Split Stance RDL	3 x 8 ea	3 x 8 ea	3 x 8 ea	3 x 6 ea	3 x 6 ea	2 x 6 ea
Single Leg Calf Raise	3 x 8 ea	3 x 8 ea	3 x 8 ea	3 x 6 ea	3 x 6 ea	2 x 6 ea
Weighted Push Up	3 x 8	3 x 8	3 x 8	3 x 6	3 x 6	2 x 6
Lat Pull Down	3 x 8	3 x 8	3 x 8	3 x 6	3 x 6	2 x 6
Session 2	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Loaded CMJ	4 x 5	4 x 5	4 x 5	4 x 5	4 x 5	2 x 5
Side Lunge	3 x 8 ea	3 x 8 ea	3 x 8 ea	3 x 6 ea	3 x 6 ea	2 x 6 ea
Prone Hamstring Curl	3 x 10	3 x 10	3 x 10	3 x 8	3 x 8	2 x 8
Seated Calf Raise	3 x 10	3 x 10	3 x 10	3 x 8	3 x 8	2 x 8
DB Shoulder Press	3 x 10	3 x 10	3 x 10	3 x 8	3 x 8	2 x 8
DB Row	3 x 10 ea	3 x 10 ea	3 x 10 ea	3 x 8 ea	3 x 8 ea	2 x 8 ea

CMJ = countermovement jump, DB = dumbbell, RDL = Romanian deadlift

between attempts. A linear position transducer (Gymaware, Mitchell, ACT 2911, Australia) was used to assess the PP.

Intervention

The intervention training program is displayed in Table 2. Both groups were required to perform strength training twice a week for six weeks. The only difference in the training program between the two groups was the intensity for the loaded CMJ. The OPLT performed the loaded CMJ at OPL from week 1 to 3. This load was increased by 5% from week 4 to 6 to induce progressive overload. The MMT performed the loaded CMJ at -20% OPL and +20% OPL for two sets each during week 1 to 3. This load was changed to by -15% and +25% OPL from week 4 to 6 to induce progressive overload. Training volume was reduced during week 6 to facilitate recovery prior to post-test.

Statistical Analysis

Data was analysed using JASP 0.18.1.0. statistical software. All tested variables were expressed by Mean (±1 SD). Within session test-retest reliability was assessed using two-way, mixed intraclass correlation coefficients (ICC) and coefficient of variation (%CV) for all measured variables. ICC values were deemed as poor, moderate, good, or excellent if lower bound 95% confidence interval (CI) of ICC values were <0.50, 0.50-0.74, 0.75-0.90, or >0.90, respectively (Koo & Li, 2016). Acceptable within-session variability was classified as <10% (Cormack et al., 2008). All assumptions to run ANOVA were checked beforehand, including normality and sphericity. A repeated measures analysis of variance (ANOVA) with Bonferroni post-hoc analysis was used to assess if any intra- and inter-group differences exist for all measured variables. Hedge's g was calculated as standardized effect size for mean comparisons, and deemed as: (i) trivial effect size if d <0.25; (ii) small effect size d = 0.25-0.50 and; (iii) moderate effect size if d = 0.50-1.0; (iv) large effect size if d >1.0 (Flanagan, 2013).

RESULTS

Reliability

The reliability data for all measured variables is displayed on Table 3. Excellent reliability was observed for CMJ jump height and 20-m sprint time. Good reliability was observed for MPF and IMTP peak force. Moderate reliability was observed for CMJ TTO, IMTP Force100 and 505 COD time.

Countermovement Jump

Data from pre- and post-test for all variables is displayed in Table 4. Significant time effect was observed for CMJ height (P = 0.002), but no group and time x group interaction effects were observed. Both groups showed significant improvement in jump height post-intervention (MMT: P = 0.025, 95%CI = 0.40 – 4.62, g = 0.48, OPLT: P = 0.003,

Table 3. Reliability data for all measured variables.

Variables	ICC (95%CI)	%CV (95%CI)
Jump Height (cm)	0.97 (0.92 – 0.99)	3.7 (2.7-5.7)
Mean Propulsion Force (N)	0.95 (0.87 – 0.98)	3.2 (2.4 - 4.9)
Time to Take-Off (ms)	0.80 (0.60 – 0.95)	5.4 (4.0 – 8.4)
IMTP Peak Force (N)	0.91 (0.78 – 0.97)	3.7 (2.8 – 5.7)
IMTP Force100 (N)	0.79 (0.65 – 0.87)	9.1 (6.7 – 15.4)
505 COD (s)	0.84 (0.62 – 0.94)	7.9 (5.9 – 12.3)
20-m Sprint (s)	0.98 (0.94 – 0.99)	0.9 (0.7 – 1.4)

505 COD = 505 change of direction, IMTP = isometric mid-thigh pull, OPL = optimum power load

95%CI = 0.67 – 2.13, *g* = 0.72). Significant time effect was also observed for MPF (*P* = 0.003), with no group and time x group interaction effect. Only MMT group showed significant increase in MPF post-intervention (*P* = 0.004, 95%CI = 17.9 – 69.1, *g* = 0.34). No significant time, group and time x group interaction effect was observed for TTO.

505 Change of Direction and 20-m Sprint

Significant time effect was observed for 505 COD time (*P* < 0.001), with no group and time x group interaction effect. The 505 COD time was significantly faster in both groups post-intervention (MMT: *P* < 0.001, 95%CI = -0.139 – -0.057, *g* = 1.12, OPLT: *P* = 0.006, 95%CI = -0.144 – -0.035, *g* = 0.36). Significant time effect was also observed for 20-m sprint (*P* < 0.001), with no group and time x group interaction effect. Both groups showed significant improvement in 20-m sprint post-intervention (MMT: *P* < 0.001, 95%CI = -0.155 – -0.064, *g* = 0.65, OPLT: *P* = 0.002, 95%CI = -0.127 – -0.045, *g* = 0.28).

Isometric Mid-Thigh Pull

Significant time effect was observed for IMTP peak force (*P* < 0.001), with no group and time x group interaction effect. Both groups showed significant increment in IMTP peak force post-intervention (MMT: *P* < 0.001, 95%CI = 93.6 – 233.9, *g* = 0.66, OPLT: *P* < 0.001, 95%CI = 72.7 – 159.0, *g* = 0.46). Significant time effect was also observed for Force100 (*P* < 0.001), with no group and time x group interaction effect. Both groups showed significant increment in Force100 post-intervention (MMT: *P* = 0.019, 95%CI = 19.7 – 167.6, *g* = 0.66, OPLT: *P* = 0.001, 95%CI = 32.9 – 91.2, *g* = 0.60).

DISCUSSION

The purpose of the current study was to compare the adaptations to loaded CMJ performed using the MMT and OPLT methods. While no statistically significant difference was observed, MMT resulted in greater effect size for the improvement of MPF, 505 COD and 20-m sprint times, and IMTP peak force. These findings suggested that MMT may be a better option to enhance these physical performance. Hence, the hypothesis was partially supported.

The current findings indicated that incorporating loaded CMJ training can result in improved CMJ performance. The effectiveness of training with OPL to improve jump height was evident in previous studies (Loturco et al., 2016). However, the magnitude improvement observed in this study was much lower than that observed by Loturco et al. (2016) (5.3% vs 11.5%). A possible reason could be due to the difference in training frequency and volume, which were higher in the previous study. Similar to the observation for OPLT, there was significant improvement in CMJ height for MMT as well. However, unlike OPL, the authors of this study are not aware of other study that investigated the effects of training with loaded CMJ using MMT. A previous study by Loturco et al. (2020), however, compared the effects of training with loaded CMJ with -20% OPL and +20% OPL. The authors reported only 0.9% and 2.6% improvement in CMJ height for the -20% and +20% OPL group, respectively. This was smaller than the 9.1% improvement in MMT group observed in the current study. This supports the findings by Hernández-Davó & Sabido (2023) which indicated that varying the resistance stimuli frequently within a training session improved can result in greater improvement to jump performance. While CMJ height was improved in OPLT, there was no significant change in either the TTO or MPF. In contrast, MMT resulted in significantly greater MPF post-intervention, although TTO also remain relatively unchanged. This was a possible reason for the non-significant greater percentage change in jump height observed in MMT than OPLT (9.1% vs 5.3%). The variation of resistance during

Table 4. Data for all performance measures. Expressed as Mean (SD).

	MMT				OPLT						
	Pre	**Post**	**%Δ**	***g***	**Pre**	**Post**	**%Δ**	***g***	**Time**	**Group**	**Time x Group**
CMJ height (cm)	30.2 (4.8)	32.7 (5.1)*	9.1 (11.3)	0.48	28.7 (1.9)	30.1 (1.8)$$	5.3 (3.8)	0.72	F = 14.839 P = 0.002	F = 0.736 P = 0.404	F = 1.198 P = 0.291
Time to Take off (s)	0.886 (0.119)	0.876 (0.103)	-0.9 (2.9)	0.09	0.785 (0.106)	0.782 (0.105)	-0.3 (1.1)	0.03	F = 1.517 P = 0.237	F = 3.429 P = 0.084	F = 0.484 P = 0.497
CMJ Mean Force (N)	1039.4 (108.3)	1082.9 (132.1)**	4.0 (2.8)	0.34	1169.4 (150.2)	1184.9 (141.4)	1.5 (3.2)	0.10	F = 12.146 P = 0.003	F = 3.276 P = 0.090	F = 2.718 P = 0.120
505 COD (s)	2.56 (0.09)	2.46 (0.08)**	-3.8 (2.0)	1.12	2.62 (0.23)	2.53 (0.24)$$	-3.4 (2.5)	0.36	F = 42.935 P < 0.001	F = 0.595 P = 0.452	F = 0.091 P = 0.767
20-m Sprint (s)	3.42 (0.16)	3.31 (0.16)**	-3.2 (1.7)	0.65	3.52 (0.28)	3.44 (0.26)$$	-2.4 (1.3)	0.28	F = 54.553 P < 0.001	F = 1.234 P = 0.284	F = 0.751 P = 0.400
IMTP Peak Force (N)	1900.8 (217.5)	2064.5 (252.5)$$	8.6 (4.5)	0.66	1784.9 (234.9)	1900.8 (242.4)**	6.6 (3.3)	0.46	F = 66.695 P < 0.001	F = 1.503 P = 0.239	F = 1.954 P = 0.183
IMTP Force100 (N)	865.5 (141.2)	959.2 (131.6)*	11.6 (11.9)	0.66	919.2 (93.6)	981.3 (103.1)$$	6.8 (3.8)	0.60	F = 18.659 P < 0.001	F = 0.465 P = 0.506	F = 0.768 P = 0.395

505 COD = 505 change of direction test, CMJ = countermovement jump, Force100 = force at 100 ms, IMTP = isometric mid-thigh pull,
**Denotes significant difference from MMT Pre (P < 0.05).*
***Denotes significant difference from MMT Pre (P < 0.01).*
$Denotes significant difference from OPLT Pre (P < 0.05).
$$Denotes significant difference from OPLT Pre (P < 0.01).

each training session in MMT allowed for participants to train at a different continuum of the force-velocity curve that possibly resulted in better ability to express force which was also previously observed by Hernández-Davó & Sabido (2023). Hence, based on the current findings, performing loaded CMJ with MMT method may be more favorable in improving CMJ height and MPF.

Similar to the results observed in previous study, the current OPLT also resulted in improved 505 COD and 20-m sprint times (Loturco et al., 2015; Loturco et al., 2016). The MMT also resulted in improvement to these two abilities to a similar magnitude as OPLT. Although the percentage improvement to both 505 COD and 20-m sprint times were similar between both groups, effect size analysis showed a greater effect in MMT than OPLT for both 505 COD and 20-m sprint (g = 1.12 vs 0.36 and 0.65 vs 0.28, respectively). A possible reason for the greater effect observed in MMT on the two abilities could be related to the concurrent greater effect on maximum strength gain as observed in the greater effect size for the improvement in IMTP peak force than OPLT (g = 0.66 vs 0.46). It has been reported that IMTP peak force is significantly and inversely correlated to COD ability and sprint times (Lum et al., 2020). In addition, it has been reported that strength increment often translate to improve sprint performance (Seitz et al., 2014). Hence, while practitioners may choose between using OPLT and MMT for improving COD and sprinting ability, MMT may provide for more favorable adaptations.

Performing heavy resistance or loaded jump training using OPLT and MMT were shown to be effective in improving maximum strength (Hernández-Davó & Sabido, 2023; Loturco et al., 2015; Loturco et al., 2016; Loturco et al., 2020). However, it was reported that frequent varying of training load, such as within session as compared to after a number of sessions, may be more effective in improving maximum strength (Hernández-Davó & Sabido, 2023). The current results support the findings of Hernández-Davó & Sabido (2023) as MMT resulted in a greater effect size for the improvement of both IMTP peak force and Force100. The reason for these findings was because training with different intensity may induce different strength adaptations (Comfort et al., 2022). For example, Comfort et al. (2022) reported that training with moderate loads resulted in greater improvement in IMTP peak force but training with heavy loads resulted in greater improvement to early force development. As force is a product of mass and acceleration, lifting lighter loads may allow for greater peak force generated due to greater acceleration. The generation of higher peak force may have resulted in greater maximal strength adaptations. On the other hand, while lifting heavy loads, individuals will need to generate high amount of force rapidly to overcome the initial inertial, assuming they were attempting to lift the load as fast as possible. Hence, resulting in greater improvement in early force development. These may explain why MMT resulted in greater effect on the improvement in both IMTP peak force and Force100 as they were required to lift both lighter and heavier load than those in OPLT.

Several limitations should be taken into account while interpreting the current results. Firstly, the sample size is limited as the study was conducted on the female softball national training squad. However, as performance measured were physical qualities (i.e. sprinting and jumping) relevant to other sports, the current findings may be applicable to athletes from other sports. Nevertheless, it is recommended for future studies to include a larger and more diverse group of participants for the findings to be generalized to a larger population. Secondly, the results are based on a six-week duration intervention with participants who just started their pre-season training. Results may differ based on training status and duration.

In summary, the current results showed that training with loaded jumps using the MMT method may be a better option than OPLT due to the possibility of inducing greater improvement in force generation capability. The possible reason for this occurrence was likely because training at different intensity leads to different neuromuscular adaptations. The greater improvement in force generation capability may translate to better athletic performance such as COD and sprinting.

PRACTICAL APPLICATION

Practitioners should take note to vary the training load of their athletes frequently in order to optimize adaptations. This would allow the athletes to train at different continuums along the velocity curve. As many sports (e.g. team sports) require athletes to perform at varying speeds and intensities, training at varying intensities may provide greater training stimulus to enhance their physical ability to meet the demand of their sports.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

FUNDING

No funding was received in order for this study to be completed.

ETHICAL APPROVAL

The study commenced after obtaining ethical approval from the Nanyang Technological University Institutional Review Board (NTU- IRB-2022-490).

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REFERENCES

1. Bauer, P., Uebellacker, F., Mitter, B., Aigner, A. J., Hasenoehrl, T., Ristl, R., Tschan, H., & Seitz, L. B. (2019). Combining higher-load and lower-load resistance training exercises: A systematic review and meta-analysis of findings from complex training studies. Journal of Science and Medicine in Sport, 22(7), 838–851.
2. Comfort, P., Dos' Santos, T., Beckham, G. K., Stone, M. H., Guppy, S. N., & Haff, G. G. (2019). Standardization and methodological considerations for the isometric midthigh pull. Strength & Conditioning Journal, 41(2), 57-79.
3. Comfort, P., Jones, P. A., Thomas, C., Dos' Santos, T., McMahon, J. J., & Suchomel, T. J. (2022). Changes in early and maximal isometric force production in response

to moderate-and high-load strength and power training. Journal of Strength & Conditioning Research, 36(3), 593-599.
4. Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing maximal neuromuscular power: part 2 – training considerations for improving maximal power production. Sports Medicine, 41(2), 125–146.
5. Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. (2008). Reliability of measures obtained during single and repeated countermovement jumps. International Journal of Sports Physiology and Performance, 3(2), 131-144.
6. Costello, J. T., Bieuzen, F., & Bleakley, C. M. (2014). Where are all the female participants in Sports and Exercise Medicine research?. European Journal of Sport Science, 14(8), 847–851.
7. Dos' Santos T, Jones PA, Comfort P, Thomas C. Effect of different onset thresholds on isometric midthigh pull force-time variables. Journal of Strength & Conditioning Research, 31(12), 3463-3473, 2017.
8. Flanagan, E. P (2013). The effect size statistic—Applications for the strength and conditioning coach. Strength and Conditioning Journal, 35(5):37-40.
9. Gabbett, T. J., Kelly, J. N., & Sheppard, J. M. (2008). Speed, change of direction speed, and reactive agility of rugby league players. Journal of Strength and Conditioning Research, 22(1), 174–181.
10. Haff, G. G., & Nimphius, S. (2012). Training principles for power. Strength & Conditioning Journal, 34(6), 2-12.
11. Harper, D. J., McBurnie, A. J., Santos, T. D., Eriksrud, O., Evans, M., Cohen, D. D., Rhodes, D., Carling, C., & Kiely, J. (2022). Biomechanical and neuromuscular performance requirements of horizontal deceleration: A review with implications for random intermittent multi-directional sports. Sports Medicine, 52(10), 2321-2354.
12. Heishman A, Daub B, Miller R, Brown B, Freitas E, Bemben M. Countermovement jump inter-limb asymmetries in collegiate basketball players. Sports 7: 103, 2019.
13. Hernández-Davó, J. L., & Sabido, R. (2023). The effect of three different resistance training programming approaches on strength gains and jumping performance. Research Quarterly for Exercise and Sport, 94(1), 1–6.
14. Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of chiropractic medicine, 15(2), 155-163.
15. Loturco, I., Dello Iacono, A., Nakamura, F. Y., Freitas, T. T., Boullosa, D., Valenzuela, P. L., Pereira, L. A., & McGuigan, M. R. (2022). The optimum power load: a simple and powerful tool for testing and training. International Journal of Sports Physiology and Performance, 17(2), 151–159.
16. Loturco, I., Nakamura, F.Y., Kobal, R., Gil, S., Pivetti, B., Pereira, L.A., & Roschel, H. (2016). Traditional periodization versus optimum training load applied to soccer players: effects on neuromuscular abilities. International Journal of Sports Medicine, 37 13, 1051-1059.
17. Loturco, I., Pereira, L.A., Kobal, R., Zanetti, V., Gil, S., Kitamura, K., Abad, C.C., & Nakamura, F.Y. (2015). Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. Journal of Sports Sciences, 33, 1283 – 1292.
18. Loturco, I., Pereira, L. A., Reis, V. P., Bishop, C., Zanetti, V., Alcaraz, P. E., Freitas, T. T., & Mcguigan, M. R. (2020). Power training in elite young soccer players: Effects of using loads above or below the optimum power zone. Journal of Sports Sciences, 38(11-12), 1416–1422.
19. Lum, D., Haff, G. G., & Barbosa, T. M. (2020). The relationship between isometric force-time characteristics and dynamic performance: a systematic review. Sports, 8(5), 63.
20. Martel, G. F., Roth, S. M., Ivey, F. M., Lemmer, J. T., Tracy, B. L., Hurlbut, D. E., ... & Rogers, M. A. (2006). Age and sex affect human muscle fibre adaptations to heavy-resistance strength training. Experimental Physiology, 91(2), 457-464.
21. Nuzzo, J. L. (2023). Narrative review of sex differences in muscle strength, endurance, activation, size, fiber type, and strength training participation rates, preferences, motivations, injuries, and neuromuscular adaptations. Journal of Strength & Conditioning Research, 37(2), 494-536.
22. Seitz, L. B., Reyes, A., Tran, T. T., de Villarreal, E. S., & Haff, G. G. (2014). Increases in lower-body strength transfer positively to sprint performance: a systematic review with meta-analysis. Sports Medicine, 44, 1693-1702.
23. Taylor, J. B., Wright, A. A., Dischiavi, S. L., Townsend, M. A., & Marmon, A. R. (2017). Activity demands during multi-directional team sports: a systematic review. Sports medicine, 47, 2533-2551.
24. Toji, H., & Kaneko, M. (2004). Effect of multiple-load training on the force-velocity relationship. Journal of Strength and Conditioning Research, 18(4), 792–795.