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Band Conditioning Contractions Result in Greater Acute Performance Enhancement When Utilising Contrast Training in Elite Same Day Concurrently Trained Team Sport Athletes

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ABSTRACT

Purpose: The aim of the current study was to assess the effect of altering conditioning contraction within contrast training on subsequent drop jump performance in the presence of same day concurrent training.

Methods: In a randomized crossover design, 8 professional Australian Football athletes completed same day skills/endurance training followed by resistance training utilizing different PAPE conditioning contractions (Strength, Band and Isometric). Conditioning contractions were performed for three sets of 3 repetitions; Strength (box squat, instructed to lift as heavy as possible), Band (band resisted, lower-force/ higher-velocity box squat) and Isometric (3 second maximal isometric quarter squat), with 3 DJ repetitions performed one minute following. Data were analyzed by fitting a mixed model (significance was set at $P \leq 0.05$) to compare changes in DJ performance to respective baseline for each protocol with Dunnett's post hoc analysis applied.

Results: Compared to baseline, Band protocol resulted in the greatest increase in reactive strength index (RSI) for set 1 ($P = 0.029$) and 2 ($P = 0.007$), Stiffness for set 1 ($P = 0.041$) and 2 ($P = 0.015$), Mean Power for set 1 ($P = 0.002$) and 2 ($P = 0.040$), and Peak Power for set 1 ($P = 0.002$). Isometric increased RSI ($P = 0.023$) and Stiffness ($P = 0.018$) for set 1 only and Strength showed no improvement.

Conclusion: Practitioners working with athletes undertaking same day concurrent training should consider alternate modes of conditioning contraction such as Band conditioning contractions when prescribing contrast training to elicit a PAPE response.

Keywords: Post-activation potentiation performance enhancement, contrast training, resistance training, concurrent training, team sport.

INTRODUCTION

There are two frequently utilized methods of resistance training (RT) within session periodization,

the traditional training approach and the contrast training approach. The contrast training method is based on the ability to utilize post-activation potentiation (PAP). PAP is the acute enhancement of force or muscle twitch contraction after a previous conditioning contraction or maximal voluntary contraction (15, 18, 37). Recent research has eluded to misalignment between PAP and contrast training, where PAP is generally associated with enhancements in muscle twitch properties and contrast training often refers to the ability to enhance voluntary force production (5). As such, the term post-activation performance enhancement (PAPE) is now considered a more appropriate term in relation to contrast training (5). Traditionally, PAP is prescribed with compound strength movements (e.g. back squat) and with a relatively high percentage of repetition maximum (80-100%) for a low amount of dynamic repetitions (≤5) followed by dynamic plyometric exercise (18, 37). PAP has been suggested to be represented by two distinct pathways; the phosphorylation of myosin regulatory light chains and alterations in neural stimulation (3, 19, 35-37). In contrast, PAPE is attributed to changes in muscle temperature and alterations to muscle force (5). Whilst PAPE is a popular prescription method in team sport environments, there is currently limited research examining the structure of contrast training on subsequent plyometric performance in professional same day concurrently trained (CT) team sport athletes.

High-intensity intermittent team sports are represented by a random and unplanned activity profile (29). The utilisation of the stretch shortening cycle (SSC) is key when performing reactive explosive high intensity actions and technical skills that directly contribute to sport performance (i.e., accelerations, decelerations and change of directions) (10). As such, the drop jump (DJ) can be utilised as a training tool to improve reactive high-intensity actions and subsequently sport performance. While previous research has utilised jump height as the primary performance measure, this is limited to being an outcome measure and provides little information as to the kinetics and kinematics of the jump performed (16, 33). Therefore, metrics that represent jump strategy are pertinent for practitioners. Ground contact time is a key measure in understanding jump performance, as the same jump height achieved by a shorter ground contact time leads to a more efficient DJ strategy. Furthermore, reactive strength index (RSI) takes into account both the flight time and ground contact time from DJ and is calculated as flight time divided by ground contact time (34). Similarly power, which is the product of force and velocity, may also provide further information as to the efficiency of the jump strategy and not simply the jump outcome. Therefore, any contrast training related chronic improvements in an athlete's RSI or power capabilities may aid in improving the performance of key technical skills and competitive match play inherent to team sports.

Particularly relevant for practitioners working within the realm of professional team sport athletes is the role of the preceding conditioning contraction for improving plyometric performance (2, 23, 32). Previous research comparing 3-repetition maximum (RM) back squat and three 3-second maximal isometric squats reported that 3 minutes following 3-RM back squat there was an 8.0 % increase in jump peak power but no improvement in jump height, whereas the isometric protocol improved both jump height and power (2.9% and 8.7%) (32). However, in the context of professional team sport athletes it is not always possible for athletes to lift heavy loads at or near maximum as recommended in the literature (17). Indeed, recent research has shown that professional Australian Football (AF) athletes when performing contrast training following skills/endurance training and asked to self-select the 'heavy' conditioning contraction load, selected loads that were below the current literature recommendations (74% ± 9% of 1-RM) (31). This can be due to several reasons; exacerbated fatigue associated with cumulative pre-season training loads; carry over fatigue resulting from the most recent game; and acute injuries/contusions from both training and matches (12). As such, exploring alternate methods of conditioning contraction to elicit a subsequent performance enhancement to plyometric performance is relevant for those working with team sport athletes.

It has been previously proposed that variations in conditioning contraction mode may impose varying levels of fatigue (22), and that this variation in fatigue may influence the resulting PAPE. As such, alternate modes of conditioning contraction that influence fatigue and subsequent PAPE differently to that of commonly utilized conditioning contractions need to be explored. For example, lower-force, higher-velocity squats through the utility of resistance bands alters both the kinetic and kinematic variables (20, 38) which could provide an alternative method to achieve an augmentation in PAPE. Indeed, previous research has shown the band squat increased peak force, peak power and velocity throughout key concentric and eccentric phases compared to free

weight squats (20, 38). The shift in force velocity profile from higher force/ lower velocity contractions to lower force/ higher velocity may offer a substitute conditioning contraction mode that requires less time under tension and produces less acute fatigue than heavier squats. Furthermore, due to the explosive nature of the DJ which requires force to be applied in minimal time, its greater similarities to higher velocity band resisted squats may result in superior PAPE of subsequent DJ than seen with traditional modes of conditioning contraction.

Limited research exists that assesses the role of altering conditioning contraction in professional team sport athletes following same day skills/endurance training. Further, participant strength has been shown to effect the PAPE response (14). Concurrently trained team sport athletes, as a result of their sport, frequently perform high-intensity intermittent activity, have high strength levels and are resistant to fatigue (4, 29). As such, this may better equip team sport athletes to respond positively to alterations in PAPE conditioning contraction such as (lower-force higher-velocity) band resisted squats. Therefore, the aim of the current study was to assess the effect of altering conditioning contraction (Strength, Band and Isometric) within contrast training on subsequent DJ performance in the presence of same day concurrent training. It was hypothesized that the Band protocol would significantly improve acute subsequent DJ performance in excess of Strength and Isometric protocols and in turn provide an alternate method to elicit PAPE in same day CT athletes.

METHODS

Experimental Approach to the Problem

In a randomized crossover design, participants completed three resistance training (RT) sessions utilizing the RT contrast training method, following a field-based skills/endurance training session. Each of the three RT contrast training sessions differed with respect to the conditioning contraction stimuli employed with the aim of achieving a PAPE response; Strength, Band and Isometric. Participants completed a same-day CT protocol where endurance training (predominately skill-based football drills with the addition of supplementary running) was completed in the morning followed by a RT session in the afternoon (Figure 1). Participants were allocated 1 hour of recovery between the endurance and RT sessions and a minimum of 48 hours was provided between the contrast training testing session and previous training session. In accordance with previous research (31), three baseline drop jumps (DJ) were performed after a standardized warm-up. Recovery between conditioning contraction and subsequent DJ utilized was 1-min, which in previous research was shown to not detrimentally effect subsequent DJ performance in this cohort of athletes (31). All participants completed familiarization to each of the conditioning stimulus protocols and drop jumps.

Subjects

Eight professional (AF) athletes (mean ± SD: age, 19.5 ± 0.5 yr; height, 186.8 ± 7.5 cm; body mass, 86.0 ± 9.9 kg; Box Squat 1RM, 146 ± 17kg; professional training age, 1.9 ± 0.8 yr) from the same Australian Football League (AFL) club participated in this in-season study. All participants competed in the national Australian Football League (AFL) competition with each providing written informed consent. Participants were free from any acute or chronic injury or medical condition during the data collection period that could affect their health or performance. If players were diagnosed as suffering from an injury, as diagnosed by club medical staff and defined as pain resulting in modified training or load, the individual's data was removed from final analysis. The project was approved by the University's Human Research Ethics Committee (DR03167).

Procedures

All participants were instructed to arrive at the training facility between 7:00 and 8:00 am before completing individual preparation for a team-based skills/endurance session. External training load of all field-based outdoor sessions (field-based skills/endurance) was monitored via *Catapult S5 OptimEye* (Catapult Innovations, Docklands Vic, Australia) global position system (GPS). Training metrics obtained from the GPS units were Training Duration [min], Total Distance meters [m] (TD), Total High Speed Running (>15 km.h^{-1}) [m] (HSR), Total Distance > 75% of an individual's maximum velocity [m] (75%), Total Distance > 85% of an individual's maximum velocity [m] (85%) and mean running speed [m.min^{-1}]. Peak maximal velocites for each participant were obtained as previously described (27). The same GPS device was worn for all outdoor training sessions by each player as per manufacturer recommendations (29). The accuracy and reliability of 10 Hz GPS units for quantifying the movement demands of team sport athletes have been

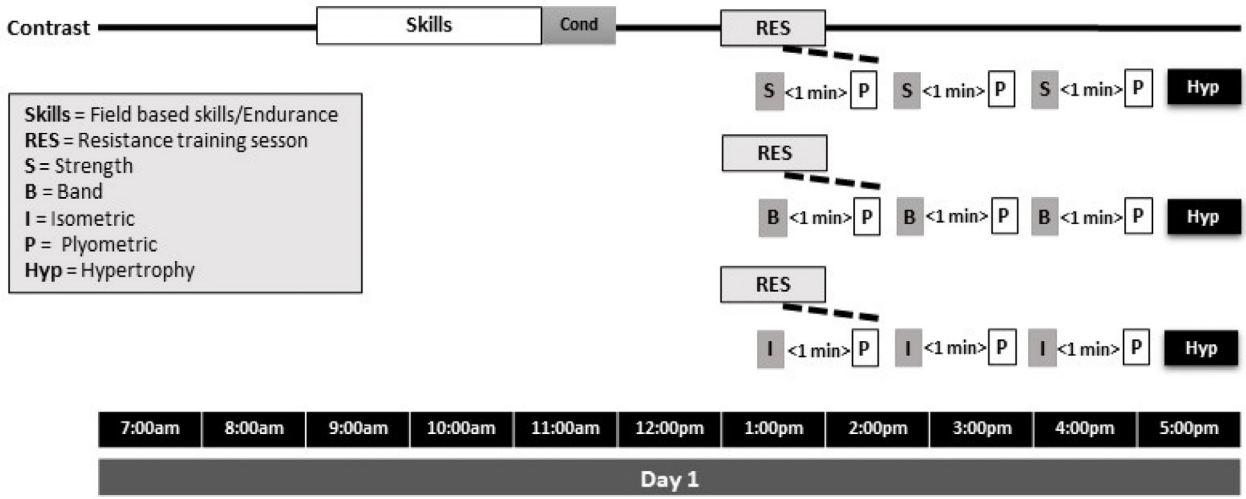

Figure 1. Overview. Timeline shows team-based skills/endurance session in the morning followed by resistance training in the afternoon with Strength, Band or Isometric Conditioning Contraction. Skills = Field based skills/Endurance; RES = Squat/ Bench Press/ Bench Pull & Supplementary exercises; S = Strength; B = Band; I = Isometric; P = Plyometric; Hyp = Hypertrophy.

previously reported (21). Following the completion of the morning field-based skills/endurance training session, participants were provided with a mixed meal targeted towards individual body composition and training goals containing variable amounts of carbohydrate and protein. After completing the meal, the participants underwent passive rest until commencement of the RT session.

Participants completed a standardized warm up at the beginning of each RT session which included bodyweight squats, mini-band lateral walks and pogo jumps followed by 3 submaximal DJ's. The participants were then given 2 minutes recovery before their baseline DJ were recorded. Participants were instructed to position their hands on the hips throughout the jump, to step off the box (30cm) and land with two feet on a force place (FD4000 dual force plates, Force Decks, Vald Performance, Newstead, QLS, AUS) simultaneously ensuring a short ground contact time and maximal rebound jump height. Participants were allowed no knee bend during flight phase. If any knee bend was observed, participants were instructed to repeat the jump. After 3 baseline jumps were completed, 2 minutes of recovery time was allowed before participants commenced their assigned conditioning contraction training protocol. In each of the three RT sessions, participants performed one of three conditioning contractions: Strength, Band or Isometric. The Strength condition consisted of a barbell box squat utilizing a self-selected 'heavy' load with participants instructed to lift as much as possible for the prescribed 3 sets of 3 reps (67% ± 9% of 1-RM). Participants were allowed to increase load (kg) from set to set if they were confident of performing 3 reps. Band condition consisted of 3 sets of 3 reps of a band (danbakerstength.com) (each blue band can add up to 28 kg) resisted box squat, with an external load of 30 kg (inclusive of bar weight). Box height was set with thighs parallel to the ground with the same box height utilised for both the Strength and Band conditions. Participants were instructed to gently touch the box (box height set with thighs parallel to ground and kept constant throughout protocol) before exploding upwards as quickly as possible. Isometric condition was completed on a custom-made Smith machine, whereby participants self-selected a quarter squat position and had the bar fixed in place at this height. Participants positioned themselves under the fixed bar, with the bar sitting on the trapezius muscle just behind the neck. While standing on the force plate, participants were instructed to push for 3 sets of 3 second efforts, with each repetition performed at a maximal effort. Each conditioning protocol was followed by a 1-min rest period, after which the participants performed 3 maximal DJ repetitions.

All data for vertical jumping were sampled at 1000 Hz on FD4000 dual force plates (Force Decks, Vald Performance, Newstead, QLS, AUS) and analysed using the ForceDecks associated software. The following variables were collected: contact time (CT) [s], flight time (FT) [ms], jump height (JH) [cm], impulse [N.s], peak power [W], mean power [W], reactive strength index ratio (RSI) (RSI = flight time [s] / contact time [s]) and Stiffness (Stiffness = peak active concentric force / change in displacement of centre of mass) [N/m] (6, 41). These methods have been proven as reliable and valid measures of assessing changes in lower body power (7, 9, 24, 26). Table 1 displays the Intraclass correlation coefficients (ICC) and coefficient of variation (CV)

Table 1. Intraclass Correlation (ICC) and Coefficient of Variation (CV) for baseline drop jumps.

	ICC	CV (%)
RSI (reactive strength index)	0.93	8.8
Stiffness (N/m)	0.84	20.7
Peak Power (W)	0.64	8.2
Mean Power (W)	0.47	9.2
Impulse (N.s)	0.92	3.1
Jump Height (cm)	0.82	6.5
Flight Time (FT) (ms)	0.83	3.1
Contact Time (CT) (s)	0.89	9.7

for these DJ outcome measures collected from the participants at baseline.

Statistical Analyses

Prior to the analysis of outcome measures, Shapiro–Wilk tests confirmed the normality and lognormality for the preceding sport specific GPS running loads and force plate data. All outcome measures for DJ performance are presented as mean ± standard deviation.

One-way ANOVA and Tukey's multiple comparison test assessed for differences between the preceding skills/endurance running loads (training duration, total distance, high-speed running, distance covered >75% and 85% maximal velocity and mean running speed) for each condition (Table 2). The subsequent analyses of DJ performance were carried out separately for each dependent variable (contact time, flight time, jump height, impulse, peak power, mean power, RSI and stiffness) with 3 comparisons per family (sets), each of the experimental sets versus respective baseline. Between group comparison of baselines was also conducted. Data in text is reported as mean difference ± standard error and p value. Due to a malfunction of the force plate software, there were 16 missing force platform values across the study of random participants. Therefore, data were analyzed by fitting a mixed model. Significance was set at $P \leq 0.05$. All data were analyzed using (GraphPad Prism Version 8.04.1, GraphPad Software, La Jolla, CA).

Results

Preceding field-based skills/endurance same day training loads are displayed in Table 2, with PAPE squat conditioning stimulus load shown in Table 3. There were significant differences in HSR in preceding skills/endurance training load, with the Band protocol having significantly greater HSR compared to Strength and Isometric protocols. Furthermore, TD and mean running speed were significantly greater in the Band protocol compared to Isometric protocol.

When comparing respective baselines for each protocol there was no significant differences (Figure 2).

For the Strength protocol, there was no significant difference for set 1, 2 or 3 compared to baseline for any outcome DJ variables (Figure 3).

For the Band protocol, there was a significant increase in RSI [FT: CT] for set 1 (mean difference (M), standard error (SE), P value (*P*)); M = 0.234, SE = 0.069, *P* = 0.029) and set 2 (M = 0.227, SE = 0.050, *P* = 0.007) (Figure 4) compared to baseline. Stiffness [N/m] increased in set 1 (M = 4921, SE = 1582, *P* = 0.041) and set 2 (M = 4604, SE = 1192, *P* = 0.015) compared to baseline (Figure 4). In addition, peak [w] and mean power [w] improved in set 1 (peak power: M =1099, SE = 207.9, *P* = 0.002) and mean power (M = 653, SE = 116.2, *P* = 0.002), whilst only mean power [w] improved in set 2 (M = 668, SE = 213.2, *P* = 0.040) compared to baseline (Figure 4).

For Isometric, there was a significant increase in RSI [FT: CT] for set 1 compared to baseline (M = 0.206, SE = 0.058, *P* = 0.023) (Figure 5) and for stiffness [N/m] for set 1 (M = 3313, SE = 889, *P* = 0.018) compared to baseline (Figure 5). No other improvements in jump variables were observed compared to baseline for Isometric.

DISCUSSION

The aim of the current study was to assess the effect of altering contrast training conditioning contraction (Strength, Band and Isometric) on subsequent DJ

Table 2. Comparisons of preceding conditioning stimulus load, box squat (kg), Band (m/s) and ISO (n). Data shown as Mean (SD) with *P* values presented.

	Strength	Band	Isometric	*P* value
Training Duration (min)	59 (11)	67 (12)	59 (5)	.242
Total Distance (m)	5154 (1008)	6857 (1462)	4533 (772)*	.010
High Speed Running (>15km/h)	1086 (529)*	1554 (291)	886 (190)*	.018
Distance covered >75% (m)	21 (20)	69 (64)	23 (13)	.079
Distance covered >85% (m)	8 (10)	30 (31)	12 (10)	.132
M/min	91 (24)	102 (11)	82 (3)*	.063

**Denotes significant difference compared to Band protocol.*

Table 3. Comparisons of within preceding conditioning stimulus load, box squat tonnage (kg), Band mean concentric velocity (m/s) and ISO peak force (n). Data shown as Mean (SD).

	Set 1	Set 2	Set 3	*P* value
Box Squat (kg)	262.2 (31.1)	309.4 (59.4) *	331.9 (63.3) *	.001
Band (m/s)	1.14 (0.01)	1.18 (0.04)	1.17 (0.05)	.080
ISO (N)	3570 (636.2)	3835 (605.0)	3979 (715.1)	.043

**Denotes difference to set 1*

performance in the presence of same day concurrent training. The main finding from the present study was that a Band type conditioning contraction had the greatest effect on subsequent drop jump performance followed by isometric conditioning contraction compared to their respective baselines when employing the contrast training method. Strength protocol had no positive effect on subsequent drop jump performance. Therefore, alternate modes of conditioning contraction can be utilized by practitioners when employing contrast training in same day concurrently trained elite team sport athletes.

The utilization of contrast training is focused on the ability to acutely augment subsequent plyometric or jump performance via the preceding conditioning contraction (37). The role of PAPE and fatigue resulting from the conditioning contraction is crucial when structuring training to optimize the performance response. Previously it has been reported that the relationship between potentiation and fatigue is reciprocal, where if fatigue is more prevalent, an acute decrease in performance is expected versus if potentiation is more pronounced then an increase in performance is expected (28). The current results report that compared to respective baselines utilizing a Band resisted box squat conditioning contraction had greater improvements on subsequent DJ performance than Strength and Isometric protocols. This novel finding adds to the existing literature, whereby previous research employees conditioning contractions of either heavy loads (high percentage of 1-RM) or maximal isometric contractions resulting in significant improvement in jump performance (8, 40). One potential reason for the lack of PAPE from the strength protocol in the present study could be the use of lighter than recommended loads, whereby participants self-selected loads of 67% ± 9% of 1-RM. Given the similarity to previous research where participants selected 74% ± 9% of 1-RM loads in a same day concurrent training model utilizing contrast training (31). It may be that professional AF and other same day concurrently trained athletes cannot always perform the subsequent resistance training session with the traditionally recommended high % loads of 1-RM in the presence of same day concurrent training (17). Moreover, the acute strength 'state' of concurrently trained athletes can vary greatly depending on a numbers of factors (e.g., the proximity of training and matches, nutritional status, sleep, arousal and acute and chronic injuries) (25). As such, it is possible that Band type conditioning contractions are more suitable, compared to heavy loads relative to 1-RM and maximal isometric loads, for team sport athletes concurrently training to achieve a PAPE response.

Currently, there is limited research investigating the impact of conditioning contraction mode on PAPE performance in the presence of same day concurrent training in team sport athletes. Previous research suggests the degree of potentiation achieved can be attributed to the type of conditioning contraction and subsequent fatigue associated (37). The present results report that the Band protocol improved RSI and stiffness for sets 1 and 2, whereas Isometric protocol increased RSI and stiffness for set 1 only.

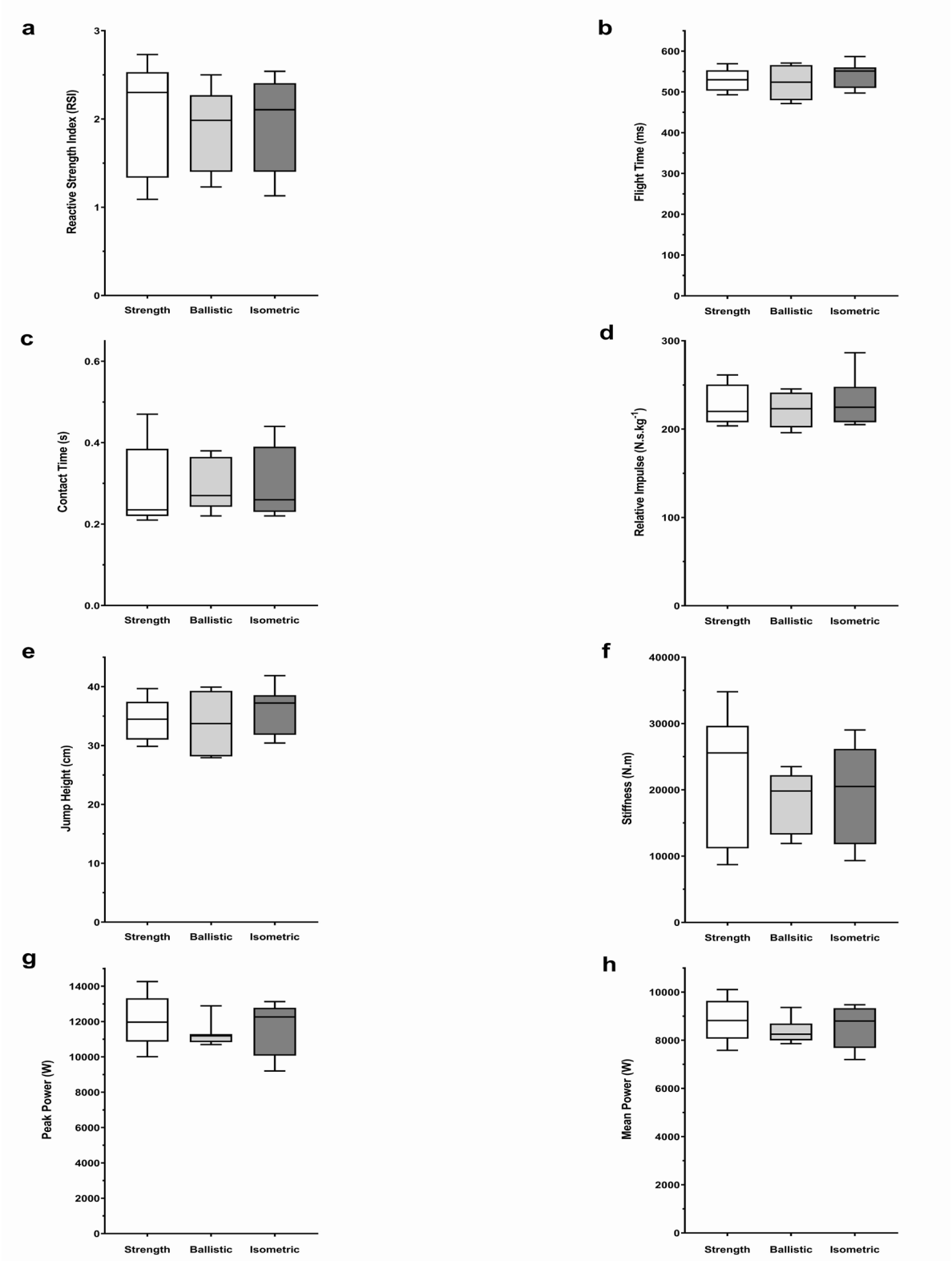

Figure 2. A box and whisker plot showing baseline drop jump performance for Strength, Band and Isometric protocols. The box represents 25th and 75th percentiles and the bars represent minimum and maximum values. a) RSI, b) Flight Time, c) Contact Time, d) Reactive Impulse, e) Jump Height, f) Stiffness, g) Peak Power and h) Mean Power.

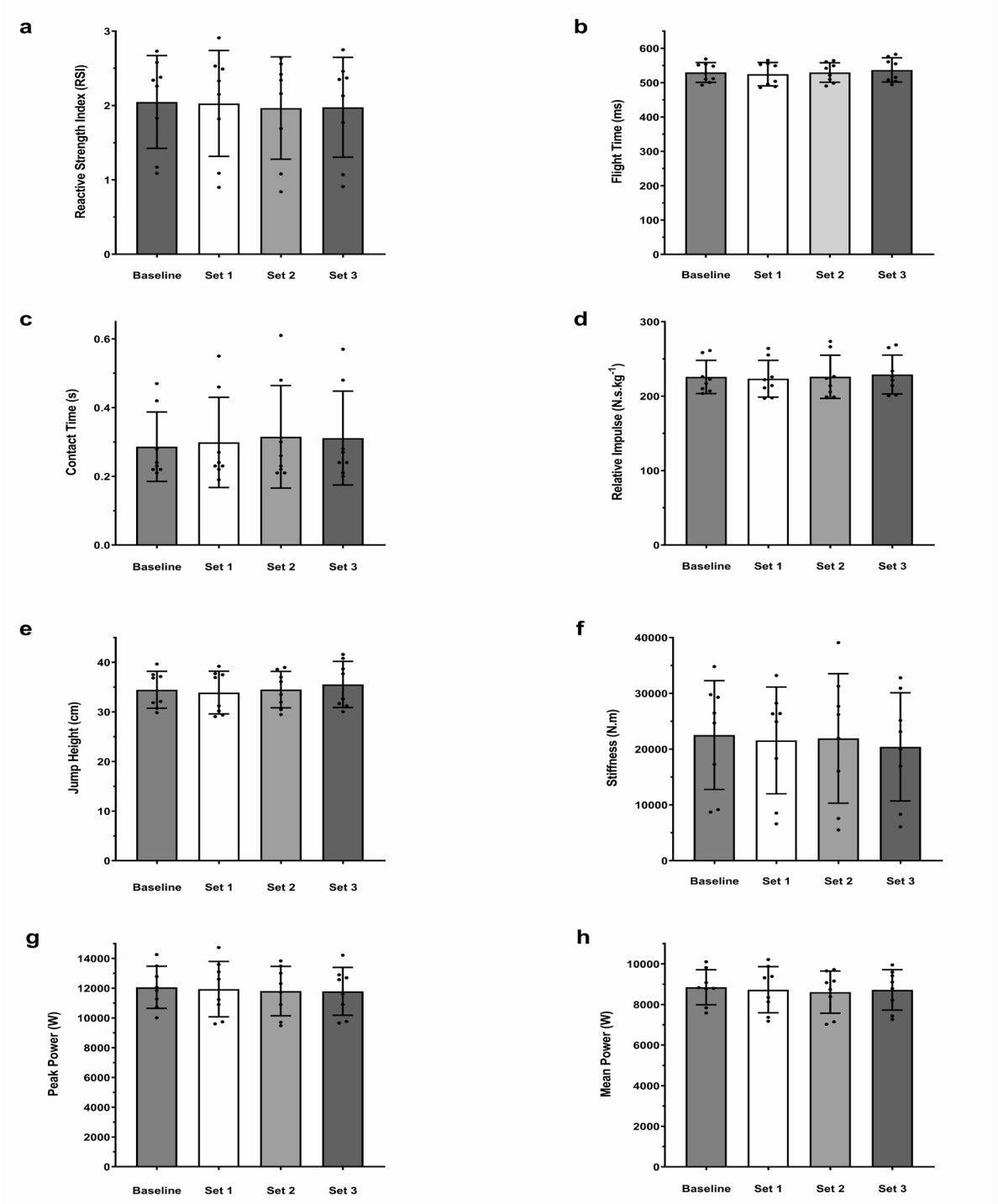

Figure 3. Comparisons compared to baseline for Strength protocol. Bars represent mean and SD values, with individual data points plotted. *Indicates *P* value <0.05. a) RSI, b) Flight Time, c) Contact Time, d) Reactive Impulse, e) Jump Height, f) Stiffness, g) Peak Power and h) Mean Power.

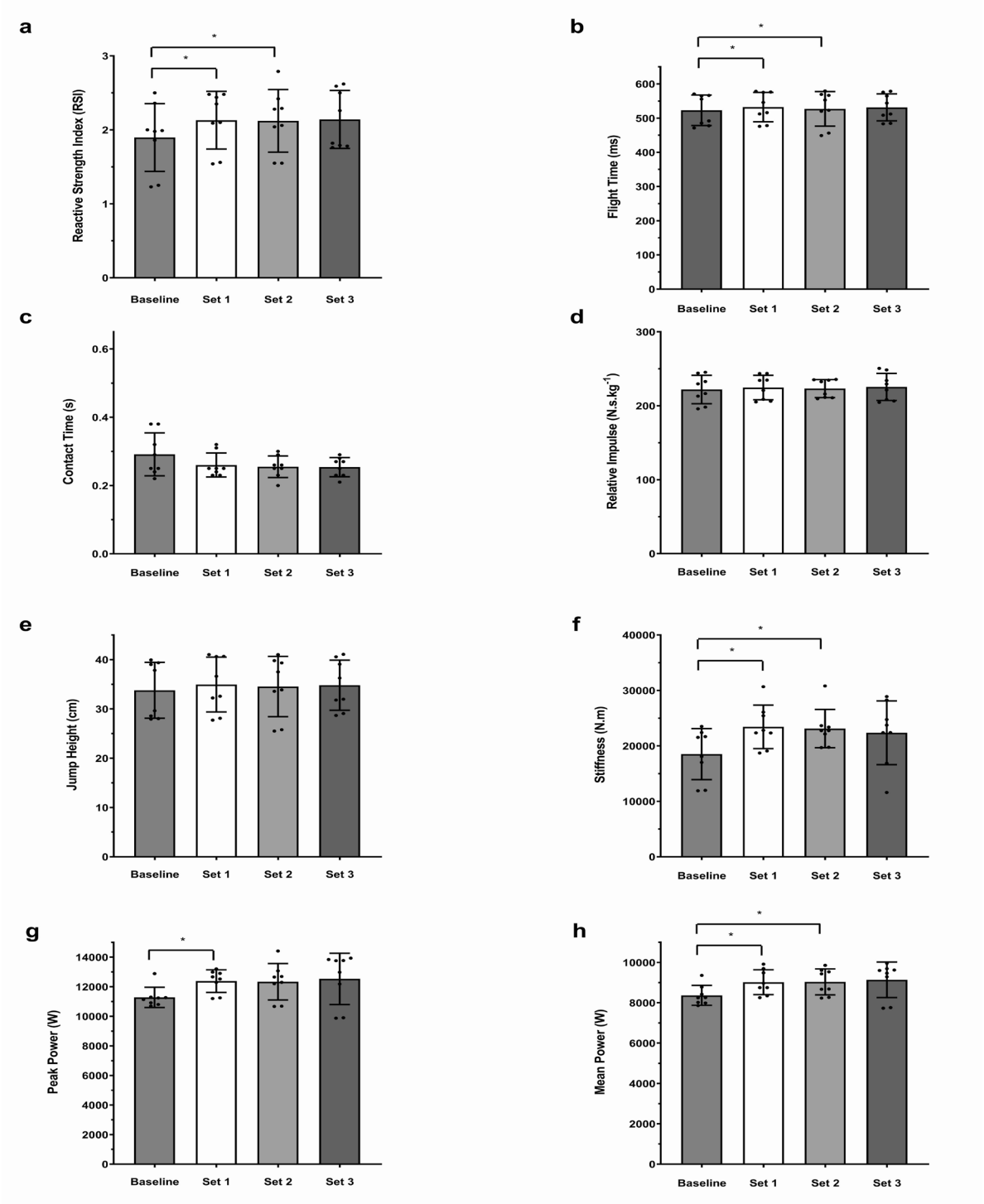

Figure 4. Comparisons compared to baseline for Band protocol. Bars represent mean and SD values, with individual data points plotted. *Indicates *P* value <0.05. a) RSI, b) Flight Time, c) Contact Time, d) Reactive Impulse, e) Jump height, f) Stiffness, g) Peak Power and h) Mean Power.

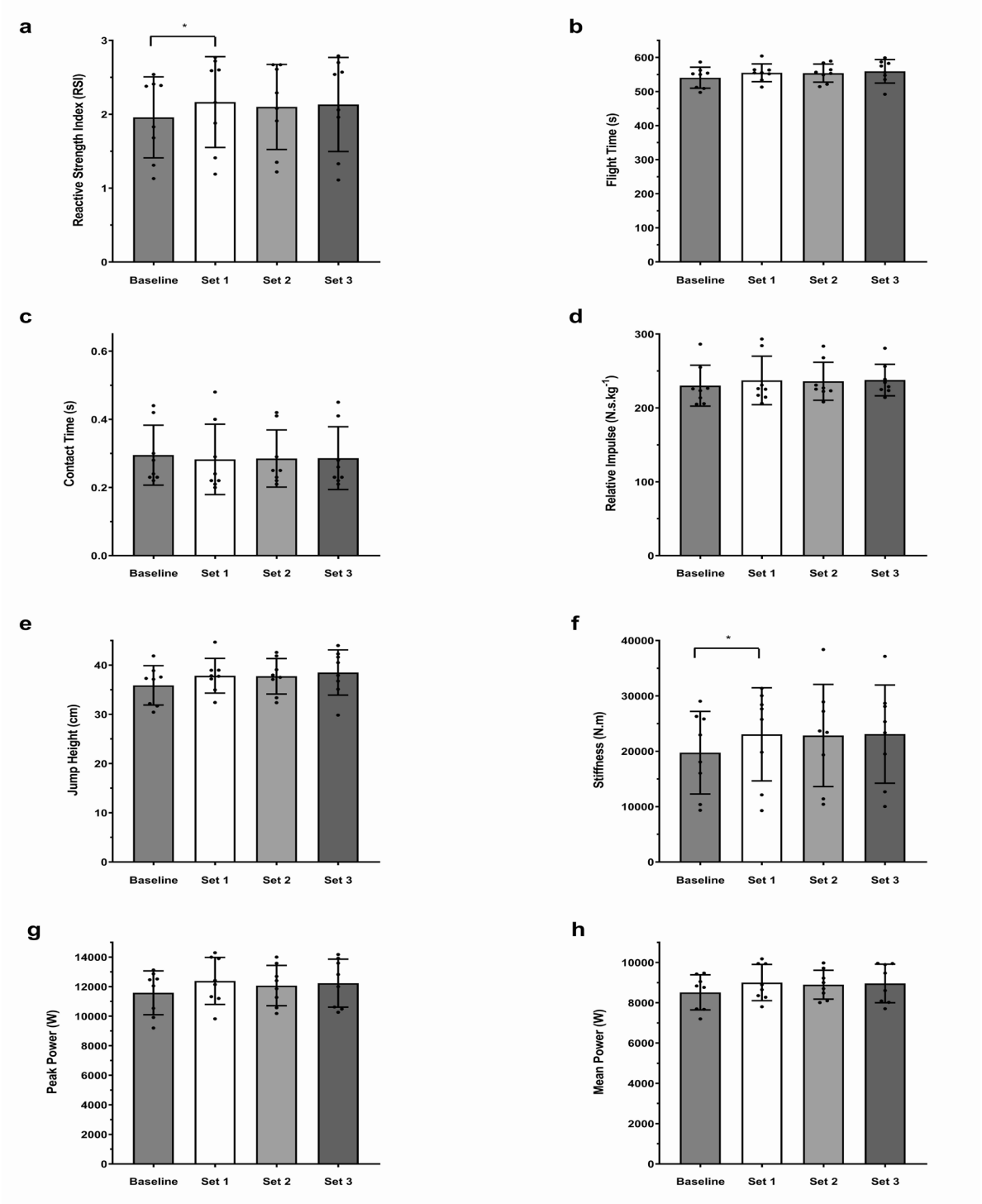

Figure 5. Comparisons compared to baseline for Isometric protocol. Bars represent mean and SD values, with individual data points plotted. *Indicates *P* value <0.05. a) RSI, b) Flight Time, c) Contact Time, d) Reactive Impulse, e) Jump height, f) Stiffness, g) Peak Power and h) Mean Power.

However, only Band increased peak and mean power. Band resisted squats, as utilized in the Band protocol, have been previously shown to augment the kinematics and kinetics of a squat compared to free weight only (20). Band resisted squats have been reported to increase force output for the last 10% of the concentric phase and first 25% of the eccentric phase, while also increasing power and velocity throughout the late portion of the concentric phase and early portion of the eccentric phase of a back squat compared to free weight only (20). These band-related alterations to the kinematic and kinetic profile of the squat may represent the mechanisms underpinning the beneficial changes to DJ performance observed as a result of the Band protocol in the current study. The Band conditioning contraction mimics the requirements of the DJ which demands force to be expressed in minimal time. These similarities in conditioning contraction and subsequent plyometric task may lead to greater performance in subsequent tasks. Due to the similarities in vertical stiffness required for the DJ and the kinetic and kinematic effects band resistance can have on the squat, increased power and force output near full extension and the requirement for the athlete to drive vertically with maximal intent into the accommodating resistance may facilitate lower-force higher-velocity band resisted squats as a suitable alternative for eliciting a PAPE response in team sport athletes. Therefore, practitioners should aim to choose the conditioning contraction with parallel kinetic and kinematic output to that of the subsequent plyometric task they aim to augment.

Given the kinematic difference between Strength, Band and Isometric contraction modes, it may be that resistance training experience and further muscle contractile history also has an impact on the PAPE response. Results of a previous meta-analysis report significant differences in jump performance when results were split into untrained (ES; 0.14, 95% CI; -0.27 ± 0.57), trained (ES; 0.29, 95% CI; 0.03 ± 0.55) and athletic (ES; 0.81, 95% CI; 0.44 ± 1.19) populations (39). In the current study, the participants had a professional training age of 1.9 years, indicating a consistent frequency of same day concurrent training history having undertaken 2 annual macrocycles in an elite sporting environment, compared to typically reported experience for untrained and trained populations. Given the demands of concurrent training, the participants may have increased motor unit synchronization, neural excitation and firing, elevated myosin regulatory light chain phosphorylation (19, 35), greater fatigue resistance and the ability to potentially recover faster following repeat explosive efforts (8, 37). As previously reported in the literature the ability of team sport athletes to repeat near maximal efforts and sprints is a key underpinning physiological trait for success (13). Therefore, the high-intensity intermittent nature of team sports training/matches and associated fatigue resistance, strength levels and frequent utilisation of the stretch shortening cycle under fatigue (4, 29) within team sport athletes may further explain the present results. As such, by way of their training and contractile history team sport athletes may respond favourably to modes of conditioning contraction that represent the right side of the force velocity curve such as band resisted lower-force/higher velocity squats, that more closely relate to the underpinning physiological demands of their chosen sport.

Although contrast training is heavily utilized in team sport settings (11, 14, 31) there is limited research examining the efficacy of contrast training that quantifies the preceding skills/endurance training load (31). In the current study the Band protocol showed greater HSR volumes than both the Strength and Isometric protocols, where total distance and mean running speed were greater for Band compared to Isometric protocol only. Previous research suggests that increasing HSR in a preceding skills/endurance training session can have a negative impact on subsequent RT performance (30). Despite this, higher HSR did not negatively influence the capacity for Band contractions to induce improvements in DJ performance in the present study. Whilst it may be suggested that greater HSR volume would have a greater negative effect on PAPE, it might be that conditioning contractions that result in a lower metabolic cost (such as of lower-force/higher velocity band resisted squats) may offset and circumvent any potential residual fatigue that may have resulted from the increased HSR from the preceding field-based skills/endurance training session. Indeed, previous research shows greater reductions in voluntary activation with low velocity or isometric contractions compared to higher velocity contractions, alluding to fast muscle shortening contractions resulting in a lower metabolic cost (1). The lower metabolic cost of lower-force/higher velocity contractions may further explain the present results. Lower force/ higher velocity contractions may offer a substitute conditioning contraction mode that requires less time under tension and produces less acute fatigue than heavier squats and maximal isometric contractions. Therefore, the Band protocol may represent a less demanding conditioning contraction compared to Strength and

Isometric protocols for utilization within contrast training during the in-season when residual fatigue may already be present.

Whilst the current research adds to the contrast training and same day concurrent training literature by exploring alternate modes of conditioning contraction within the presence of same day concurrent training in professional team sport athletes, there are current limitations that need to be addressed. The present study was only able to have 8 professional AF team sport athletes complete all three testing sessions during this in season study. Future research should consider larger sample sizes of team sport athletes and AF athletes from opposing teams could increase the generalizability and confidence of these results. Whilst the assessment of preceding skill/endurance load is an important component of the current research, skills/endurance training loads were significantly higher during the Band protocol compared to Isometric protocol. Although from a research quality control perspective similar preceding training load is desired making a direct comparison between protocols as uncomplicated as possible; this isn't always achievable when conducting applied research in the field with professional athletes. It was therefore of significance that even with these higher preceding running loads as evident with the Band protocol, that the Band protocol appeared to offer improvements in more kinetic and kinematic DJ metrics compared to respective baselines than Strength and Isometric protocols. Future research should consider varying the skills/endurance training load with distinctive session targets (e.g., high speed and low volume and low speed and high volume) while assessing the impact of alternate conditioning contraction modes on PAPE in same day concurrently trained athletes.

CONCLUSION

The current study shows that alternate methods of PAPE conditioning contraction can be applied to elicit an acute performance enhancement with professional same day concurrently trained athletes. Indeed, the Band squat protocol had the greatest impact on subsequent performance enhancement. The PAPE response is likely contraction mode specific as changes to the kinematics and kinetics of the conditioning contraction mode had an impact on key determinants of reactive strength performance. Therefore, conditioning contractions that reflect the outcomes of the subsequent plyometric or power movement are worth consideration. The training and contractile history of the participants is also an important factor to consider. Team sport athletes exhibit high levels of fatigue resistance and the ability to perform high-intensity actions under fatigue is a key requirement of team sports. Further, the fatigue associated with conditioning contraction may also influence the PAPE response and selecting contraction modes that may result in a lower metabolic cost, can aid in managing the crucial relationship between fatigue and performance enhancement. Therefore, the band resisted conditioning contraction offers an alternate contrast training conditioning contraction mode compared to traditional near maximum repetition loads in the presence of same day concurrent training in professional team sport athletes and should be considered in the organisation of training when trying to augment an acute performance enhancement in subsequent plyometric tasks.

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