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Utilising short duration recovery when employing the resistance training contrast method does not negatively affect subsequent jump performance in the presence of concurrent training

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Background: Little is known about contrast training and post-activation potentiation (PAP) in a same day concurrent training model. The aim of the current study was to examine the use of short duration (≤4 min) recovery durations on drop jump performance in same day concurrently trained athletes.

Methods: Ten professional Australian Rules footballers (age, 20.6 ± 1.9 yr; height, 184.8 ± 6.9 cm; body mass, 85.8 ± 8.4 kg) completed two resistance training sessions with different PAP recovery durations; 1-min (ONE) and 4-min (FOUR), 1 h following a field-based endurance session. Baseline drop jumps were collected, followed by 3 sets of squats (where each athlete was encouraged to lift as heavy as they could), followed by 3 maximal drop jumps.

Results: Significance was set at $P \leq 0.05$. There were no significant differences between baseline and experimental sets 1, 2 and 3 for reactive strength index (RSI), flight time, and total and relative impulse for either recovery duration. However, for contact time, ONE baseline was significantly different from set 2 (mean difference; 95% CI, 0.029; 0.000 to 0.057 s, $P = 0.047$, ES; 95% CI, -0.27; -1.20 to 0.66). For RSI and flight time, ONE was significantly higher than FOUR (RSI: 0.367; 0.091 to 0.642, $P = 0.010$, ES; 95% CI, 0.52; -0.37 to 1.42; flight time: 0.033; 0.003 to 0.063 s, $P = 0.027$, ES; 95% CI, 0.86; -0.06 to 1.78).

Discussion: PAP that utilizes short recovery durations provides another ecologically valid method of within-session resistance training periodization for team sport athletes.

Manuscript Title: Utilising short duration recovery when employing the resistance training contrast method does not negatively affect subsequent jump performance in the presence of concurrent training.

Running Head: Post-activation potentiation in team sports athletes

Research was conducted at Metricon Stadium, the training facility of the Gold Coast Suns Football Club.

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Abstract

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Key Words: Training organisation, post-activation potentiation, periodisation, team sport.

INTRODUCTION

Within the strength and conditioning literature, there are two within-session resistance training periodisation models commonly used in athlete preparation. The traditional training approach structures training in accordance to the estimated cost of fatigue whereby plyometric, power and compound exercises are completed at the beginning of the resistance training session (1, 2). The second method is contrast training which typically involves the performance of a few repetitions with high loads of compound exercises, e.g., squats or power cleans, shortly followed by a lighter power or plyometric exercise (3). This contrast mode of resistance training has become increasingly popular within team sport settings (4-6).

The benefit of using the contrast training method reflects the ability to utilise post-activation potentiation (PAP). PAP is defined as the enhancement of force or muscle twitch contraction after a previous conditioning contraction or maximal voluntary contraction (7-9). PAP is utilised on the premise that the preceding strength-based movement may result in a complementary improvement in performance of the following jump or plyometric movement (9, 10). PAP is generally elicited when a small number of dynamic repetitions (≤5) are performed as explosively as possible with loads of 80-100% of repetition maximum (8, 9). The mechanistic underpinnings of PAP reflect two major pathways; the phosphorylation of myosin regulatory light chains (9, 11-14) and alterations in neural stimulation (9). Of specific relevance to the planning, prescription and organisation of resistance training in team sports, the rest interval in between the conditioning contraction and subsequent plyometric or power exercise has been previously reported to affect the PAP effect (10).

To optimise the PAP response, a meta-analysis has indicated that 8 to 12 minutes of recovery after the conditioning contraction is required to induce the greatest PAP response (10). However, in the context of team sport training, where large numbers of athletes train simultaneously within scheduled time blocks, the elongated recovery period of 8-12 minutes is impractical. In team sport players, a positive PAP response has been demonstrated when utilising short (≤4 minute) recovery periods. For example, Mitchell and Sale (15) demonstrated in resistance-trained university rugby union players a 2.9% increase in CMJ height 4 minutes after 5-RM back squat with a self-selected load. The variations in the optimal recovery period to maximise the PAP response may reflect variations in the PAP protocol (e.g. intensity of the conditioning stimulus and the magnitude and time course of resulting fatigue) and the characteristics (e.g. strength and fatigability) of the participants (10, 16). In team sport settings where training schedules are dense, the PAP recovery period presents as a challenge since limited time is allocated to resistance-training, particularly in-season (17, 18). Thus, a shorter recovery duration between contraction stimulus and subsequent plyometric/jump exercise is highly appealing as it represents a more ecologically valid training methodology for use in high-performance sport.

In further considering the ecological relevance of PAP duration time, no previous PAP related research has been conducted in the presence of same day concurrent training (CT) (4, 6). Indeed, given that concurrently-trained athletes typically, by way of their training history, have high strength levels and are generally fatigue-resistant, they may be able to demonstrate significant PAP effects with shorter rest periods than that commonly recommended in the strength and conditioning literature (10, 15). Moreover, the training phase (i.e., pre- versus in-season) (18) and distribution of load (19) across a week are altered highlighting why PAP recovery time course may be important in relation to resistance training organisation. The aim of the current study was to examine the effect of short duration contrast training recovery time course (1-min) versus longer duration recovery time course (4-min) on drop jump (DJ) performance in the presence of same day concurrent training. We hypothesised that both short duration protocols would not attenuate subsequent DJ perfromance and will provide an ecologically valid recovery time course for PAP in same day CT athletes.

MATERIALS AND METHODS

In a repeated-measures randomised design, participants completed two resistance training (RT) sessions with different PAP recovery durations; 1-min (ONE) and 4-min (FOUR), following a field-based endurance session. Briefly, participants undertook a same-day CT protocol where endurance training (predominately skill-based drills with the addition of top-up running) was completed in the morning followed by a RT session in the afternoon (20). All participants were provided 1 hour of recovery between the endurance and RT training sessions. Baseline drop jumps (DJ) were performed after a standardised warm-up, followed by 3 sets of squats where each athlete was encouraged to lift as heavy as they could safely to do so. DJ were then performed with either ONE or FOUR recovery after each set of squats. All participants had previously participated in and were familiar with heavy barbell box squatting and plyometrics movements where a range of force plate measured training metrics were assessed.

Ten professional Australian football (AF) athletes (mean ± SD: age, 20.6 ± 1.9 yr; height, 184.8 ± 6.9 cm; body mass, 85.8 ± 8.4 kg; Box Squat 1RM, 150 ± 16kg) from the same Australian Football League (AFL) club participated in this pre-season study. The athletes competed in the national AFL competition with each providing written informed consent. All participants were required to be free from any injury or medical conditions that may affect their performance or endanger their health. If players suffered an injury, defined as pain resulting in modified load, data was excluded from final analysis. The project was approved by the institutions Human Research Ethics Committee (DR03167).

Participants arrived 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 the 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 were Total Distance (m) (TD), Total High Speed Running (>15 $km{\cdot}h^{-1}$) (m) (HSR), Total Distance above 75% of an individual's maximum velocity (m) (75%), Total Distance above 85% of an individual's maximum velocity (m) (85%) and mean running speed ($m{\cdot}min^{-1}$). Maximal velocities were obtained as previously described (21). Each player wore the same GPS device across both outdoor sessions to account for between unit errors (22) as per manufacturer instructions (18). The accuracy and reliability of 10 Hz GPS units for quantifying the movement demands of team sport athletes have been previously reported (23).

After the completion of the field-based skills/endurance session, participants consumed a mixed meal containing variable amounts of carbohydrate and protein, targeted towards each participants' own personal body composition and training goals. This was followed by passive rest until commencement of the RT session. At the beginning of the subsequent RT session, participants completed a standardised warm up which included bodyweight squats, mini-band lateral walks and pogo jumps followed by 3 submaximal DJ. The participants were then given 2 minutes recovery before their baseline DJ were recorded. Participants were instructed to place hands on hips and to hold them there throughout the jump. Participants were then instructed to step off the box (30cm) and land with two feet onto a force place (400 series force plate, Fitness Technology, Adelaide, SA, Australia) simultaneously ensuring a short ground contact time and maximal rebound jump height with the aim to jump as high as possible. No knee bend was allowed during flight phase. If knee bend was observed, the jump was repeated. After baseline jumps were completed, 2 minutes of recovery time was allowed then participants commenced the contrast training protocol.

Participants were instructed to complete a Barbell box squat utilising a self-selected 'heavy' load with participants instructed to lift as much as possible for the prescribed sets and reps. Three repetitions of the Barbell box squat (74% ± 9% of 1-RM) followed by a 1 minute or 4 minute rest period between each squat set before performing 3 DJ repetitions. Force plate variables of contact time (CT) (s), flight time (FT) (s), impulse (N.s), relative impulse ($N.s.kg^{-1}$) and reactive strength index (RSI) (RSI = flight time (s) / contact time (s)) (24, 25) were collected and recorded via the associated computer software (Ballistic Measurement System; Fitness Technology). These methods have been previously proven as reliable and valid measures of assessing changes in lower body power (26-29).

Prior to the analysis of outcome measures, Shapiro-Wilk tests for normality and lognormality were demonstrated for the preceding sport specific running loads and PAP squat conditioning stimulus. All outcome measures for DJ performance including modified RSI, impulse, relative impulse, flight time and contact time are presented as mean ± standard deviation. Paired t-test and Wilcoxon tests were utilized to assess significant differences between individual GPS training metrics (total distance, high-speed running, distance covered >75% and 85% maximal velocity and m/min) and PAP squat tonnage between the ONE and FOUR protocols. The subsequent analyses were carried out separately for each dependent variable (RSI, impulse, relative impulse, flight time and contact time) with 3 comparisons per family (sets). Because of missing values, these data were analyzed by fitting a mixed model, rather than by repeated measures ANOVA which cannot handle missing values. Significance was set at P ≤ 0.05. All data were analyzed using (GraphPad Prism Version 8.04.1, GraphPad Software, La Jolla, CA). Subsequently, bias corrected Hedges' g standardised effect sizes ± 95% confidence limits were calculated using group means ± SDs via a customised Excel spreadsheet. Modified Cohens' d thresholds of small (0.2), moderate (0.5), and large (>0.8) were used to determine the magnitude of effect (30).

RESULTS

Preceding field-based skills/endurance (sport specific) same day running loads that precede the PAP protocols are displayed in Table 1 with PAP squat conditioning stimulus tonnage is shown in Table 2. There were no significant differences in either sport-specific running loads or PAP conditioning stimulus load between the ONE and FOUR protocols.

Table 1 about here

Table 2 about here

There were no significant difference between baseline ONE and FOUR conditions for any of the jump performance variables (Fig. 1). Within condition analyses between baseline and experimental sets 1, 2 and 3 revealed no significant difference for RSI, flight time, total and relative impulse (Fig. 2 and Fig. 3). However, for contact time, ONE baseline was different from set 2 only (mean difference; 95% CI, 0.029; 0.000 to 0.057 s, P = 0.047, ES; 95% CI, -0.27; -1.20 to 0.66) with no significant differences observed for FOUR.

Figure 1 about here

Figure 2 about here

Figure 3 about here

Between condition set comparisons for both conditions are summarized in Fig. 4. For RSI, there was no difference between conditions for set 1 (mean difference; 95% CI, 0.200; -0.214 to 0.612, P = 0.472, ES; 95% CI, 0.26; -0.62 to 1.14) and set 2 (0.309; -0.114 to 0.733, P = 0.162, ES; 95% CI, 0.45; -0.48 to 1.39). However, for set 3, RSI was significantly higher for the ONE than FOUR condition (0.367; 0.091 to 0.642, P = 0.010, ES; 95% CI, 0.52; -0.37 to 1.42) (Fig. 4a).

Figure 4 about here

Consistent with RSI, there was no difference between conditions for flight time for set 1 (0.027; -0.026 to 0.080 s, P = 0.435, ES; 95% CI, 0.62; -0.28 to 1.52) and set 2 (0.014; -0.048 to 0.078 s, P = 0.870, ES; 95% CI, 0.34; -0.59 to 1.27). However, for set 3, flight time was greater for the ONE than FOUR condition (0.033; 0.003 to 0.063 s, P = 0.027, ES; 95% CI, 0.86; -0.06 to 1.78) (Fig. 4d).

For absolute impulse (N.s), there was no difference between conditions for set 1 (373; -2932 to 3678 N.s, P = 0.984, ES; 95% CI, 0.07; -0.81 to 0.94), set 2 (2348; -1763 to 6459 N.s, P = 0.314, ES; 95% CI, 0.37; -0.56 to 1.30) or set 3 (2744; -255 to 5744 N.s, P = 0.074, ES; 95% CI, 0.50; -0.39 to 1.39) (Fig. 4b). Similarly, relative impulse ($N.skg^{-1}$) showed no difference between conditions (Set 1: 6.54; -31.47 to 44.56 $N.s.kg^{-1}$, P = 0.948, ES; 95% CI, 0.08; -0.79 to 0.96; Set

2: 34.57; -17.72 to 86.86 N.s.kg^{-1}, P = 0.217, ES; 95% CI, 0.42; -0.51 to 1.36; Set 3: 33.92; -5.58 to 73.42 N.s.kg^{-1}, P = 0.097, ES; 95% CI, 0.45; -0.44 to 1.33) (Fig. 4c).

For contact time there was no difference between conditions for any of the 3 sets (Set 1: 0.003; -0.034 to 0.040 s, P = 0.992, ES; 95% CI, 0.06; -0.82 to 0.94; Set 2: -0.014; -0.053 to 0.024 s, P = 0.622, -ES; 95% CI, 0.27; -1.20 to 0.66; Set 3: -0.017; -0.038 to 0.004 s, P = 0.138, ES; 95% CI, -0.26; -1.14 to 0.62) (Fig. 4e).

DISCUSSION

The major finding of the current study was that ONE and FOUR had no negative effect on subsequent drop jump performance compared to respective baselines following skills-specific endurance training. Furthermore, when comparing ONE versus FOUR between sets, both RSI and flight time significantly improved in set 3 with ONE recovery compared to FOUR recovery. Taken together, these data have implications for the organization and planning of contrast resistance training in team sport settings where many athletes have relatively limited time to perform resistance training. Specifically, the present results suggest that concurrent trained athletes with a strong aerobic/anaerobic conditioning base may be able to utilize shorter RT rest periods than is currently recommended for most other individuals.

The benefit of using CT reflects the ability to utilise preceding strength-based movement to improve performance of the subsequent jump or plyometric movement (9). In the current study we observed no detrimental effect of utilising short 1- and 4-min recovery durations on subsequent drop jump performance following field-based skills/endurance running loads. This finding contributes to the current contrast training research literature, where a previous meta-analysis suggest that 8-12 minutes recovery after the conditioning contraction produces the greatest PAP effect (10). Importantly, individual studies presented in the meta-analysis indicate that the resultant PAP may be observed anywhere from between 4-24 minutes (10). However, due to the complex nature of team sports weekly dense schedules (18) where several other aspects of coaching, recovery and mental well-being are required, if employing the recommended 8-12 minute recovery period (10) between 3-4 sets of heavy back squat exercise and subsequent plyometric exercise, the time to complete these exercises would be >40 minutes. This length of recovery period provides limited time to complete additional exercises within a typical resistance training session of 60 min and is impractical in the applied high-performance team training setting. As such, the 1-min and 4-min recovery durations may be a time efficient contrast training modality given there was no negative effect on DJ performance compared to baseline.

The utility of the DJ in the current study and not CMJ can be explained by the short contact time required as part of an efficient DJ (4, 5, 31). This short contact is represented by a fast stretch shortening cycle (SSC) which is defined as ground reaction forces ranging from 100-250 ms (32). The present results showed an increase in RSI and FT in set 3 of ONE compared to FOUR. These findings are important as RSI, expressed as the relationship between flight and contact time, represents explosive strength and the ability to develop maximal force in minimal time. Indeed, the ability to perform explosive actions utilising the SSC is a requisite for most sports (33). Given that high-intensity intermittent activity requires accelerations, change of direction and decelerations to be performed with maximal force almost instantaneously through competition (18, 23), RSI is a particularly important attribute for team sport athletes. Furthermore, it has been shown that in athletes who have suffered significant lower limb injures that that the ability to produce force quickly is often attenuated in both the acute rehab and post return to play period (34, 35). Thus, the current results present a useful method of within resistance training organisation that can augment RSI for concurrently trained athletes such as team sport athletes.

The relationship between PAP and fatigue is important when optimising the potentiation response. AF and more broadly team sport athletes possess a high aerobic capacity, and as team sports require repeated high-intensity actions throughout training and matches this may explain the present results showing the ability to recover adequately when utilising short duration recovery periods. Our results show no detrimental effect of short duration (<4 min) recovery periods on subsequent kinetic or kinematic variables of jump performance and that ONE was more beneficial than FOUR. Previous research utilising 11 university rugby union players tested the effect of a 5-RM back squat on PAP and subsequent CMJ performance with results showing a 2.9% increase in CMJ height 4 minutes after a 5-RM back squat (15). This finding may be explained by research showing twitch potentiation to be greatest immediately following a prior conditioning contraction (8, 36). However, although twitch potentiation may be the greatest immediately following a prior conditioning contraction, there also exists a high level of fatigue that could limit subsequent maximal performance (4, 37). For example, Pearson and Hussain (37) observed an increase in twitch torque of the knee extensors but no significant effect on CMJ jump height, jump power, rate of force development or take-off velocity 4 minutes post either a 3, 5 or 7 second isometric half squat MVC in recreationally trained men. The researchers suggested that PAP was repressed by fatigue in the other musculature used during the conditioning stimulus, where twitch torque was only measured in the quadriceps (37). This may suggest a reciprocal relationship between fatigue and potentiation whereby if fatigue is favoured then a decrease in performance can be expected. Consequently, if potentiation is more pronounced, then an increase in performance might be expected (38).

In the present study, the participants preceded the resistance training session by a sport-specific endurance training session typically completed as part of their normal training routines. This prior training suggests some residual fatigue upon commencing the subsequent resistance training session undertaken one hour later. As such, we instructed the participants to self-select their conditioning stimulus load while being told to lift as heavy as they could do safely. We observed that the self-selected conditioning stimulus equated to 74% ± 9% of 1-RM which is less than the previous PAP recommendations of 80% 1-RM (9). In the context of concurrent training athletes undertaking preceding high-intensity intermittent activities, acute strength 'state' can fluctuate based on arousal, preceding activity, diet and sleep (39) inferring that the preceding sport-specific endurance session may influence subsequent resistance training performance. Consistent with this suggestion, we have previously demonstrated that sport-specific endurance running loads negatively affect subsequent same day RT performance (20), suggesting that team sport athletes may not lift >80% 1-RM due to residual fatigue. In support of the efficacy of lower conditioning stimulus loads, previous research in national level Olympic lifters report increased CMJ performance following 'moderate' loads (45-75% RM) in a back squat (40). In addition, a meta-analysis indicates that moderate (60-84%) vs heavy loads (>85%) (ES: 1.06 vs 0.31), multiple set vs single set (ES: 0.66 vs 0.24) and athletic vs untrained cohorts (ES: 0.81 vs 0.14) result in an increase in power augmentation in subsequent potentiation tasks (41). Greater RT experience results in increased neural firing, motor unit synchronisation (42) and elevated myosin regulatory light chain phosphorylation activity (11, 13, 14). As such, it may be suggested that greater training experience facilitates the relationship between potentiation and fatigue, and the acute strength 'state' of the athlete can fluctuate, thus, current recommendations of >80% 1-RM for the conditioning contraction stimulus should only be considered a guideline.

Contrast training offers another method of within resistance training periodisation. However, little research has employed concurrently trained athletes as the experimental cohort (4, 6) and no research has assessed the PAP response in a same day concurrent training model where the preceding field-based skills/endurance training load has been reported. The strength of the present study was that the preceding skills/endurance training load was matched between the ONE and FOUR groups. Furthermore, the self-selected conditioning stimulus load was consistent between groups. In addition, the current collection period was undertaken during the in-season period where the focus is solely on being in peak condition for competition and subsequent recovery for the following game. This provides a high level of ecological validity as high performance athletes such as those involved with the present study will often self-select their individual resistance training loads based on their individual recovery status following the most recent competitive match. This meant that athletes lifted under the recommended 80% 1-RM previously reported in previous PAP research, making comparisons with research utilising >90% 1-RM difficult (43-45). Given this 'lower' conditioning stimulus load, it could be suggested that subsequent drop jump performance was compromised. However, we note that drop jump performance following the conditioning stimulus was comparable to baseline meaning there was minimal detrimental effect of the lower prior PAP stimulus.

A major barrier to the prescription of contrast training to elicit a PAP response in a professional team setting is that coaches and athletes are typically under significant time constraints with limited time devoted to resistance training within a demanding weekly training schedule. This is particularly evident during the competition phase of the season where the sole focus is recovery before the next competitive game. If the rest periods required for potentiation to exceed fatigue are too large, it would be likely that strength and conditioning coaches working in high performance sporting organisations would have to reduce training volume or increase the duration of each resistance training session, both of which are not practical. Therefore, the high ecological validity of short duration (1 min) recovery periods within contrast training observed in the present study are of increased interest to those that work in high performance team training environments.

CONCLUSION

The present findings suggest the utilization of PAP within a same day concurrent training team sport model, where short duration recovery periods between conditioning stimulus and subsequent plyometric (jumping) tasks can be implemented without concern of negatively affecting the subsequent plyometric task performance. PAP that utilizes short recovery durations provides another within resistance training periodization strategy for team sport athletes. The findings suggest that short duration (1 min) recovery periods provides an ecologically valid method of utilizing contrast training and PAP strategies within concurrently trained athletes who may have constraints on the time they have to perform resistance training, especially during the in-season phase.

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Figure 1. A box and whisker plot showing baseline drop jump performance for 1 min and 4 min protocols. The box represents 25^{th} and 75^{th} percentiles and the bars represent minimum and maximum values.

Figure 2. Baseline and set comparisons for 1 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.

Figure 3. Baseline and set comparisons for 4 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.

Figure 4. Between condition set comparisons for 1 min and 4 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.

Table 1(on next page)

Table 1. Comparisons of 1 min vs 4 min protocols for preceding sports specific running loads.

Table 1. Comparisons of 1 min vs 4 min protocols for preceding sports specific running loads.

	Total Distance (m)		**High Speed Running (>15km/h)**		**Distance covered >75% (m)**		**Distance covered >85% (m)**		**M/min**	
	1 min	**4 min**	**1 min**	**4 min**	**1 min**	**4 min**	**1 min**	**4 min**	**1 min**	**4 min**
Mean (SD)	7912 (1258)	7805 (1299)	2338 (772)	2280 (829)	138 (80.4)	159 (113)	34.5 (26.7)	42.9 (45.2)	99 (13.7)	96 (15.8)
P value	0.724		0.800		0.695		0.882		0.695	
ES (95% CI)	0.08 (-0.80 – 0.96)		0.07 (-0.81 – 0.95)		-0.21 (-1.08 – 0.67)		-0.22 (-1.10 – 0.66)		0.19 (-0.68 – 1.07)	

Table 2(on next page)

Table 2. Comparisons of 1 min vs 4 min protocols for total tonnage of preceding conditioning stimulus (box squat)

1

Table 2. Comparisons of 1 min vs 4 min protocols for total tonnage of preceding conditioning stimulus (box squat)

	Set 1 (kg) 1 min	Set 1 (kg) 4 min	Set 2 (kg) 1 min	Set 2 (kg) 4 min	Set 3 (kg) 1 min	Set 3 (kg) 4 min
Mean (SD)	299 (48.2)	291 (47.0)	318 (49.9)	318 (45.2)	327 (56.0)	327 (42.9)
P value	0.655		>0.999		>0.999	
ES (95 % CI)	0.16 (-0.72 – 1.04)		0.00 (-0.88 – 0.88)		0.00 (-0.88 – 0.88)	

Figure 1

A box and whisker plot showing baseline drop jump performance for 1 min and 4 min protocols. The box represents 25th and 75th percentiles and the bars represent minimum and maximum values.

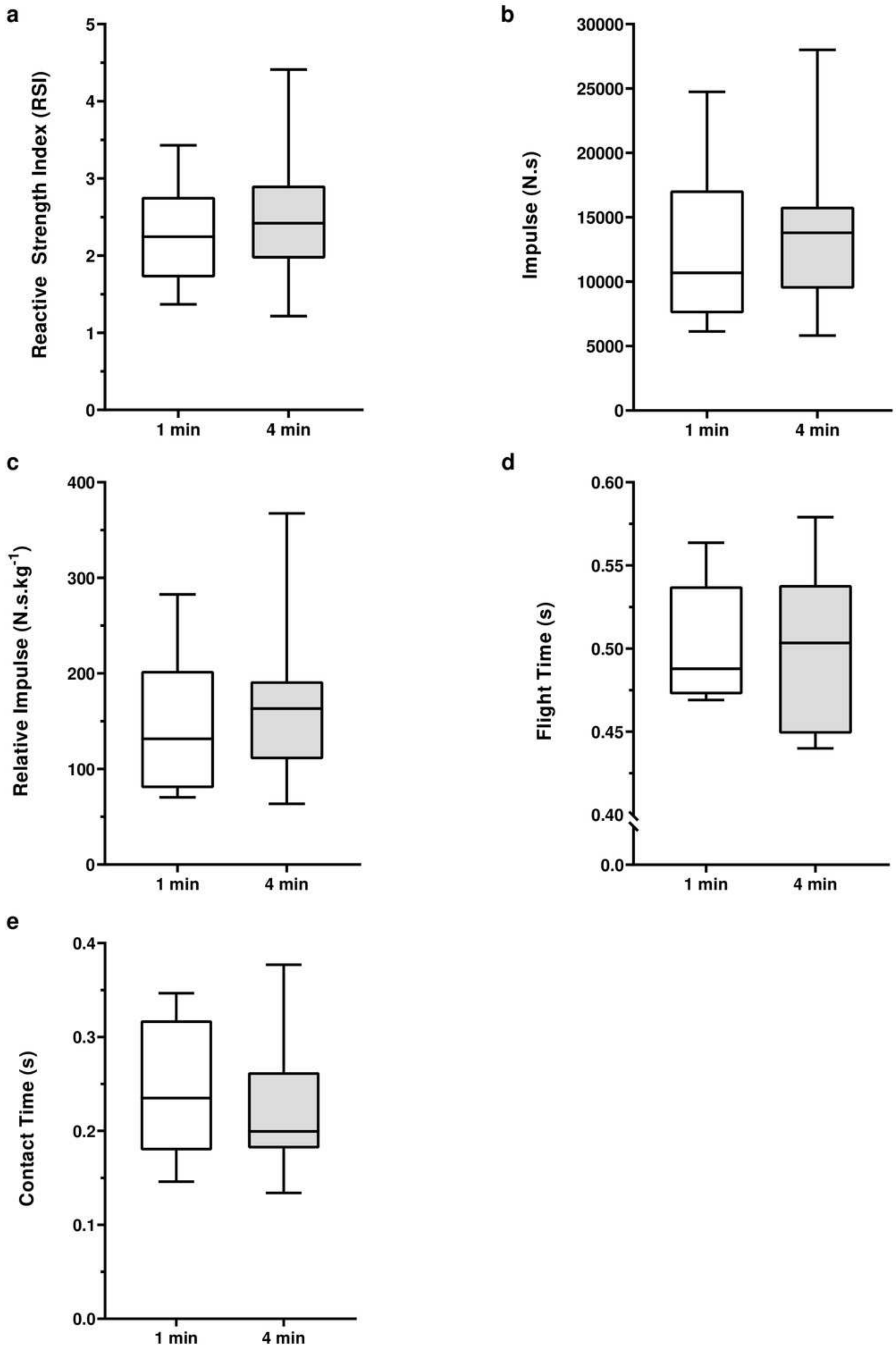

a
Reactive Strength Index (RSI)
5
4
3
2
1
0
1 min
4 min
b
Impulse (N.s)
30000
25000
20000
15000
10000
5000
0
1 min
4 min
c
Relative Impulse (N.s.kg-1)
400
300
200
100
0
1 min
4 min
d
Flight Time (s)
0.60
0.55
0.50
0.45
0.40
0.0
1 min
4 min
e
Contact Time (s)
0.4
0.3
0.2
0.1
0.0
1 min
4 min

Figure 2

Baseline and set comparisons for 1 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.

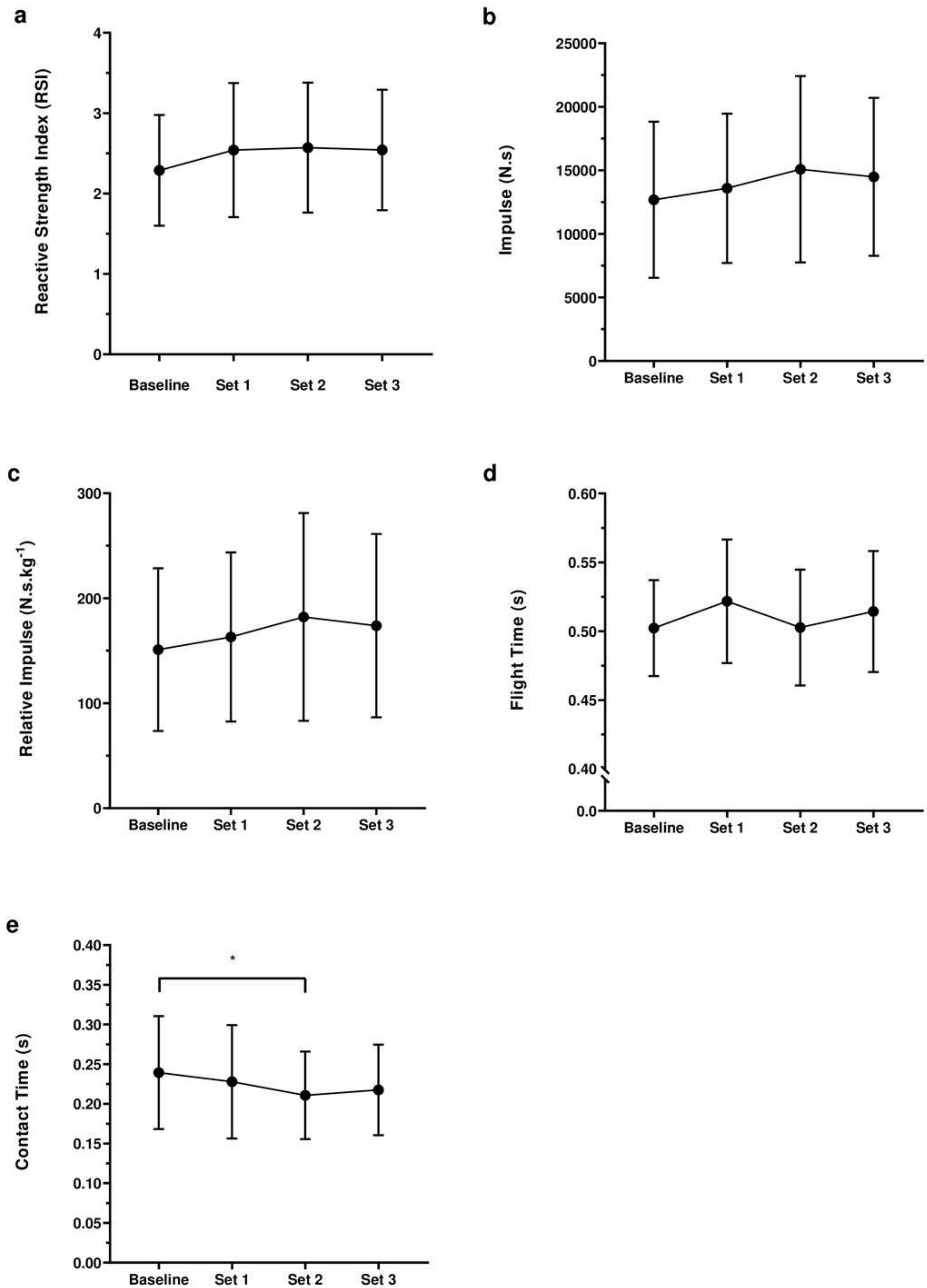

a
Reactive Strength Index (RSI)
0
1
2
3
4
Baseline
Set 1
Set 2
Set 3
b
Impulse (N.s)
0
5000
10000
15000
20000
25000
Baseline
Set 1
Set 2
Set 3
c
Relative Impulse (N.s.kg-1)
0
100
200
300
Baseline
Set 1
Set 2
Set 3
d
Flight Time (s)
0.0
0.40
0.45
0.50
0.55
0.60
Baseline
Set 1
Set 2
Set 3
e
Contact Time (s)
*
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Baseline
Set 1
Set 2
Set 3

Figure 3

Baseline and set comparisons for 4 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.

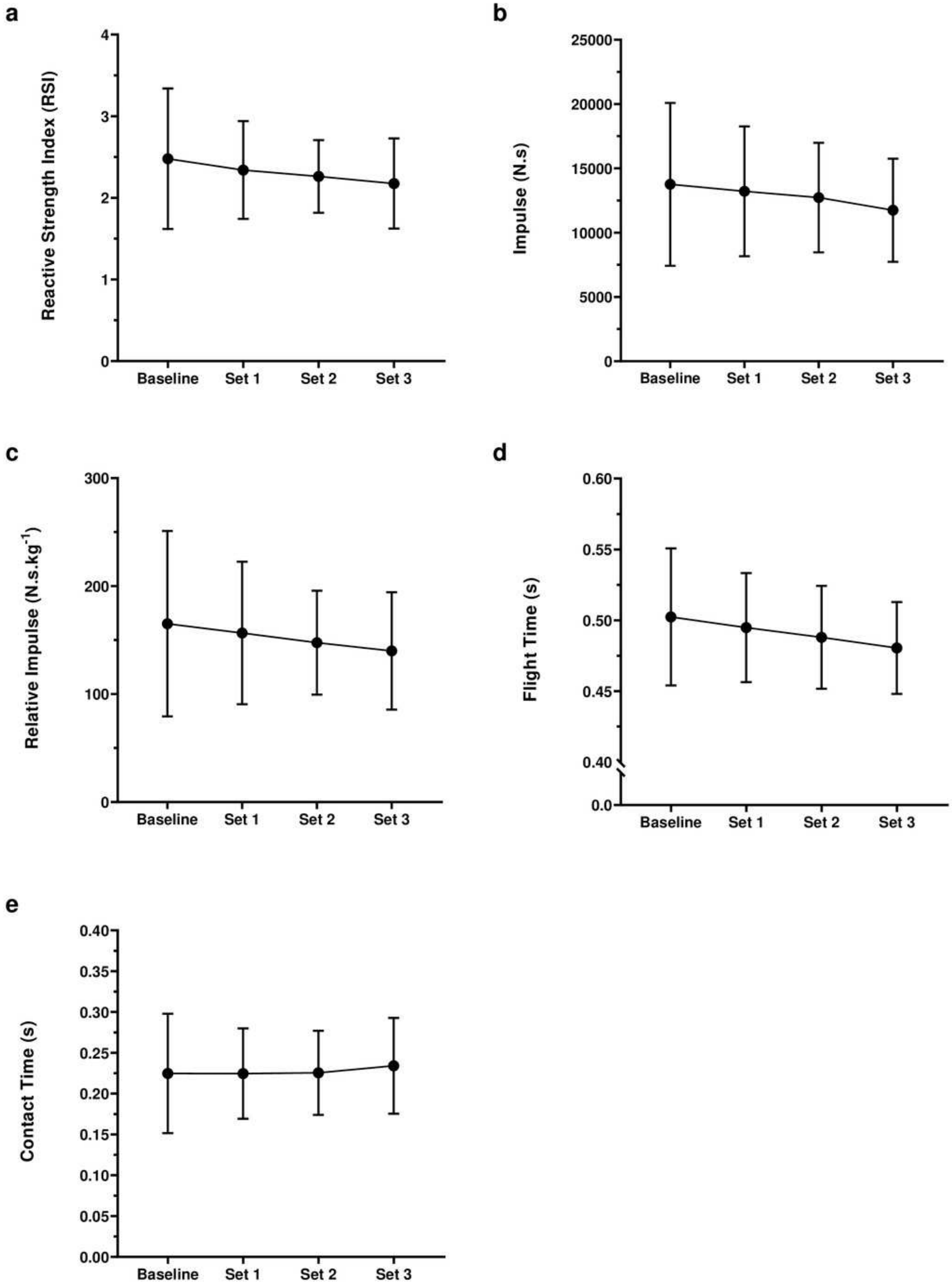
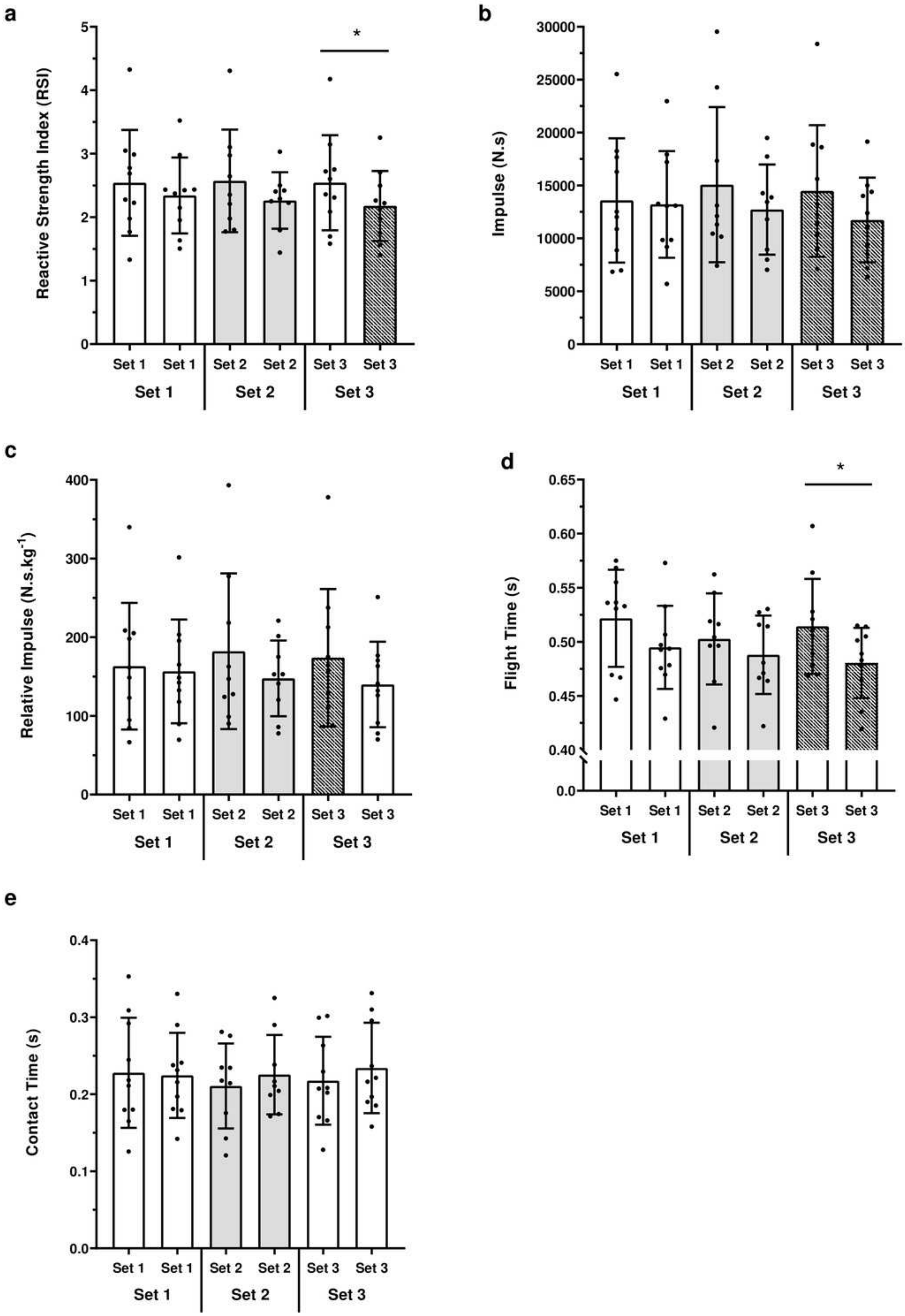

a
Reactive Strength Index (RSI)
0
1
2
3
4
Baseline
Set 1
Set 2
Set 3
b
Impulse (N.s)
0
5000
10000
15000
20000
25000
Baseline
Set 1
Set 2
Set 3
c
Relative Impulse (N.s.kg-1)
0
100
200
300
Baseline
Set 1
Set 2
Set 3
d
Flight Time (s)
0.0
0.40
0.45
0.50
0.55
0.60
Baseline
Set 1
Set 2
Set 3
e
Contact Time (s)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Baseline
Set 1
Set 2
Set 3

Figure 4

Between condition set comparisons for 1 min and 4 min protocols. Bars represent mean and SD values, with individual data points plotted. * indicates P value <0.05.



a
Reactive Strength Index (RSI)
*
b
Impulse (N.s)
c
Relative Impulse (N.s.kg-1)
d
Flight Time (s)
*
e
Contact Time (s)
Set 1
Set 2
Set 3